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Division of Agricultural Sciences
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ECONOMIC EFFICIENCY IN ASSEMBLY AND PROCESSING LIMA BEANS FOR FREEZING

Robert H. Reed

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FOREWORD

This is the fourth in a series of research reports by the University of California on the competitive position of the western frozen fruit and vegetable industry being conducted under a regional research project by the Agricultural Experiment Stations of the states of California, Oregon, Washington, and Hawaii in cooperation with the Agricultural Marketing Service, U. S. Department of Agriculture.

Previous reports in this series by the California Experiment Station have dealt with a survey[1] of the industry on the Pacific Coast, costs and efficiency in processing California[2] strawberries, and regional production trends and costs in the major[3] strawberry producing areas.

The present report concerns economic efficiency in the processing and assembling of Lima beans for freezing. It is based on studies of operations in California frozen fruit and vegetable plants made in 1957 and 1958. Future reports will include additional studies of processing plant costs and efficiency, freezing costs, demand and price relationships of frozen fruits and vegetables, and interregional competition in the industry.

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The study would not have been possible without wholehearted cooperation from the industry. While it is difficult to single out individuals in this connection, the author wishes to extend his particular thanks to the following men and organizations: R. Beverly, Food Machinery Corporation; E. Boone, John Inglis Frozen Foods Company; C. Calleros, Sacramento Freezers, Inc.; K. M. Eberts, Stokely-Van Camp, Inc.; R. G. Free, California Consumers Corp.; V. Gross, Spiegl Farms, Inc.; G. Harris, Walnut Creek Sheet Metal Co.; N. Jozovich and Company; J. Q. Leavitt and Company; J. C. Martin, Knudsen Frozen Foods Co.; R. Shaw, Watsonville Canning Company; L. States, Ocean Shore Iron Works; and F. B. Voit, Patterson Frozen Foods Company.

ECONOMIC EFFICIENCY IN ASSEMBLY AND PROCESSING LIMA BEANS FOR FREEZING

by

Robert H. Reed[1]

INTRODUCTION

Of the many factors affecting costs of preparing Lima beans for freezing, the most significant are the methods used at particular stages of harvesting and assembling raw product and in processing plant operation, the quality of raw product, style of pack, rate of plant output, and length of operating season. This report is designed to show how variations in these factors affect the cost of processing Lima beans,[2] to provide a basis for comparing alternative methods of operation, and to present data useful in planning new construction or changes in existing facilities. It is also intended to furnish data for incorporation in a later study of multiple-product plant operations and to contribute to future studies of interregional competition among fruits and vegetables processed by freezing.

Sources of Data

Data on labor and equipment utilization were obtained through processor interviews; time and production studies of actual plant operation; and analyses of operating and accounting record data, equipment inventories, and plant layouts in 10 California Lima bean freezing plants in 1957 and 1958. Eight of these plants processed both Fordhook and Baby varieties, while two specialized in the latter variety. Capacity output capabilities in these plants ranged from approximately 5,000 to 30,000 pounds per hour of operation.

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[1] Agricultural Economist, Agricultural Marketing Service, U. S. Department of Agriculture, and Associate in the Agricultural Experiment Station, College of Agriculture, University of California.

[2] The term "processing" as used in this report includes all the activities involved in handling, preparing, and freezing Lima beans.

Supplementary data for certain job and equipment categories were obtained from seven plants processing strawberries. Data concerning equipment replacement costs and operation were developed from information obtained from major equipment companies, custom manufacturers, and contractors.

Production Standards

The development of production standards for labor and equipment was complicated because most of the plants studied processed both Fordhook and Baby Lima bean varieties. Each Fordhook bean averages from 2 to 2-1/2 times larger than the Baby Lima variety; and, consequently, most of the processing equipment will handle slightly higher capacities of the latter type. All in-plant production standards used in this study are for the Fordhook variety, except for the hand-sort operation where the standards are in terms of the Baby Lima variety.1/ The differences in standards are slight, however, and have negligible effect on the labor and equipment requirements used in this report.

The work standards in this study do not represent peak performances of the most efficient workers. Instead, they represent a level of job performance that could be maintained by typical workers in plants organized so as to result in minimum unavoidable delay. Since excess delay on individual jobs was observed in most plants, these standards exceed the average level of performance observed in actual plant operation. They tend to fall about halfway between the observed average of rates actually attained and the highest individual performance rate.2/

Production standards for labor were derived from production and time studies wherever this technique was applicable to measure unit time required to perform a given operation. This involved estimating net time expended in actual performance of the operation as well as the minimum additional allowances for

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1/ On an equal weight basis, 100 Fordhook beans are on the average roughly equivalent to 283 Baby Lima beans.

2/ For a detailed discussion of work measurement methodology, refer to French, B. C., L. L. Sammet, and R. G. Bressler, "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears," Hilgardia, vol. 24, no. 19, July, 1956.

See Also Sammet, "Economic and Engineering Factors in Agricultural Processing Plant Design" (unpublished Ph.D. thesis, University of California, Berkeley, 1958).

unproductive time, such as rest periods, unavoidable delays, and personal time. For example, production studies of the job of setting off and palletizing cased Lima beans indicated net working time—including necessary miscellaneous operations—averaged 0.1093 man-minutes per case.[1] With additional allowances amounting to 15 per cent of the total work time, estimated gross unit time per case was 0.1286 man-minutesper case. This is equivalent to a "standard" production rate of 467 cases per man-hour.

For jobs are not adapted to measurement by time and production studies, operating and accounting record data were used to establish work standards. Jobs in this category include machine-paced jobs, supply men, utility workers, housekeeping, and hand-sort workers.[2]

Equipment standards, reflecting capacity output rates, were developed from studies of plant record data, production studies of actual operations, specifications of equipment manufacturers, and processor interviews. Supplementary equipment data, such as motor horsepower and operating and service requirements, were obtained as a basis for calculating operating inputs.

Estimation of Costs

Variable Costs

Variable costs include expenses for labor, materials, electric power, variable repair costs, and other expense directly related to volume of output. Labor costs with each method and output rate considered were calculated by applying typical wage rates to estimated crew requirements.[3]

The method of estimating other variable costs, such as electric power, fuel, water, steam, packaging materials, and variable maintenance—related to methods used and equipment requirements at capacity rates of output—are set forth in appropriate sections of the analysis that follows.

1/ Based on 24-10 ounce cartons per case.

2/ See page 27 where accounting and operating data are used in the development of hand-sort standards.

3/ Current wage rates of the Collective Bargaining Agreement between the Frozen Food Operators and the California State Council of Cannery Unions were used in calculating labor costs. The wage rates used were increased 6 per cent to allow for employer payroll contributions such as social security, paid vacations, and fringe benefits.

Investment Replacement Costs

Installed equipment replacement costs with different methods of operation and rates of output were calculated by applying cost rates obtained from equipment manufacturers and contractors to the estimated quantities required of each equipment item. Replacement costs of building and industrial piping and wiring are based on engineering estimates of the costs of constructing or installing required quantities of these services. The physical quantities in relation to plant capacity on which these estimates are based were developed in studies of space requirements and equipment layout in efficiently organized plants. These costs were estimated during the first quarter of 1958 and reflect the price level prevailing at that time.

An annual fixed charge, expressed as a percentage of equipment replacement cost, was used to reduce replacement cost to an annual basis. These charges include allowances for depreciation, taxes, insurance, interest on investment, and fixed repairs and maintenance.

Total Annual Costs

Estimation of total annual costs was facilitated by combining closely related processing operations into several operating stages or components and making separate analysis of each.[1] Total annual costs for each stage, related to methods used, hourly rates of output, and length of operating season, were calculated by multiplying the hourly variable cost by the hours operated per season and adding the annual fixed charge. These cost estimates provide the basis for comparing relative costs of different methods of operation and for selection of the most efficient organization for each stage of processing.[2]

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[1] An operating stage comprises a series of closely related activities directly involved in the physical handling or processing of the product. Examples are vining, cleaning, blanching, maturity grading, visual inspection and grading, packaging, casing, freezing, etc. General cost components include cost that are not directly related to a specific operating stage. Examples of general costs include supervision and miscellaneous labor, plant administration, etc.

[2] Efficient organization as used here involves the selection from among alternative methods or techniques, that combination which will result in least cost for any given output rate (size of operation) and length of operating season.

Aggregation of costs representing efficient stage organization, along with general cost components not associated with specific operating stages, gives total annual cost for the entire plant and field processing activities. These costs, related to size of plant and length of operating season, comprise the total annual cost of processing Lima beans with efficient plant and field organization. They are not the costs of a particular plant or plants. Rather, they express costs with attainable levels of efficiency for any volume of output. Total annual costs developed in this manner are referred to as long-run or planning costs. They are particularly useful in economic analysis of plant costs and to management as an aid in planning new plant construction or changes in existing facilities.

OPERATING STAGES AND COST COMPONENTS

The principal steps in the preparation of Lima beans for freezing--including both field and plant operations--are illustrated in the product flow diagram (Figure 1) and the plant layout drawing (Figure 2).

The field operations consist of vining or shelling the beans and transporting them to the receiving station of the freezing plant. Some of the initial cleaning operations may also be accomplished at the vining site. At the freezing plant, the product is pumped, flumed, or otherwise conveyed from the receiving station through a series of in-plant operations. These include initial or additional cleaning, quality separation, blanching, visual inspection and manual quality grading, filling or packaging cartons or containers of various sizes, wrapping or labeling, freezing, casing, and warehousing.

The operations performed in most processing activities can be accomplished by one or more alternative methods. Since estimation of the relative costs of alternative methods of operation is facilitated by combining closely related operations into several plant operating stages or components, field and plant operations have been classified into 10 operating stages and 4 general cost components. The operating stages include: (1) vining; (2) transportation to plant; (3) receiving, initial cleaning, and quality grading: (4) blanching and second quality grading; (5) visual inspection and manual quality grading; (6) filling and packaging; (7) variable water costs; (8) casing; (9) freezing and initial storage; and (10) in-plant transportation of cased goods and packaging materials. General cost components include: (1) investment cost of plant buildings, water piping, and electrical wiring; (2) supervision and miscellaneous labor; (3) plant administration; and (4) miscellaneous equipment.

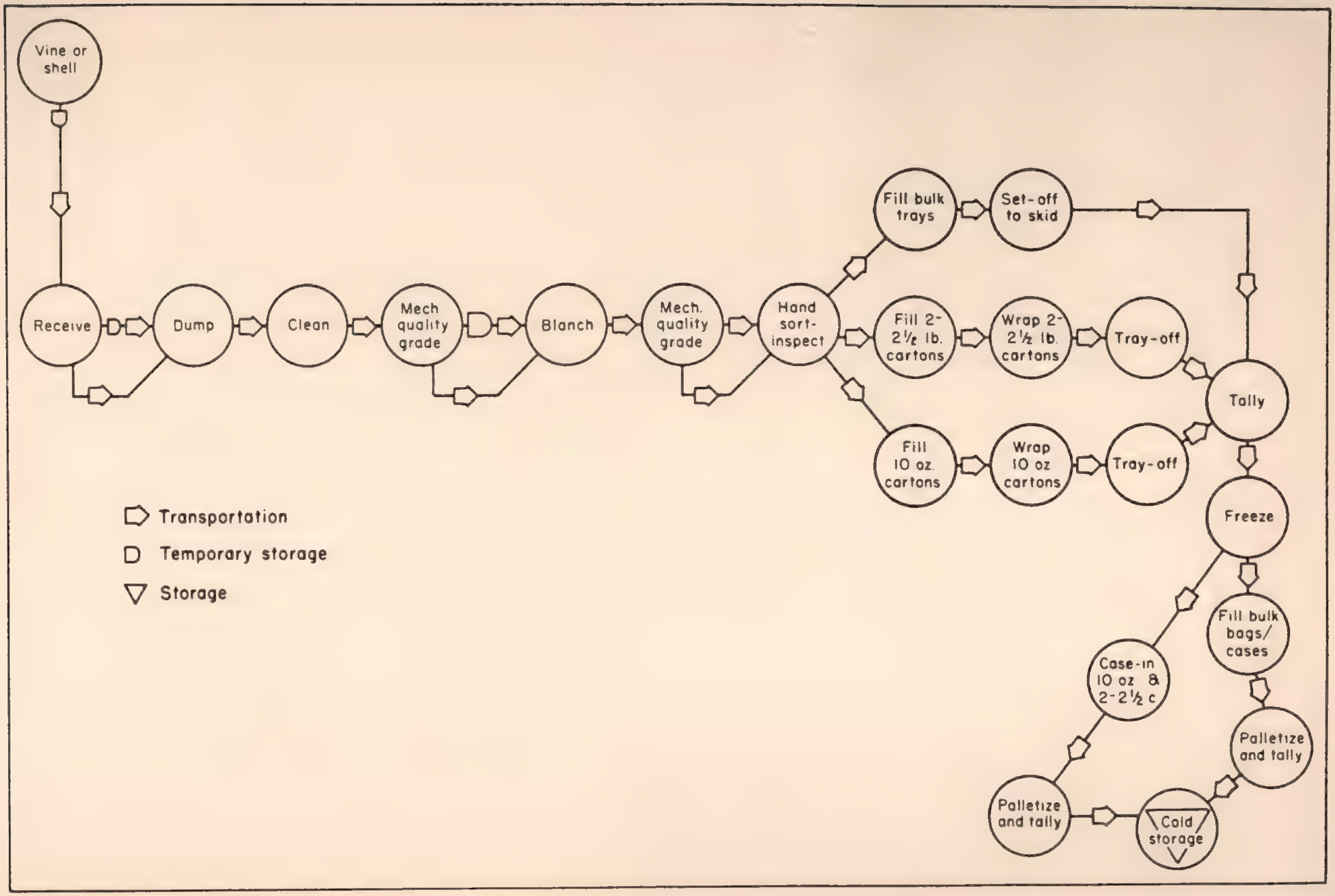

Figure 1. Process Flow Diagram for Frozen Lima Bean Processing. California, 1958.

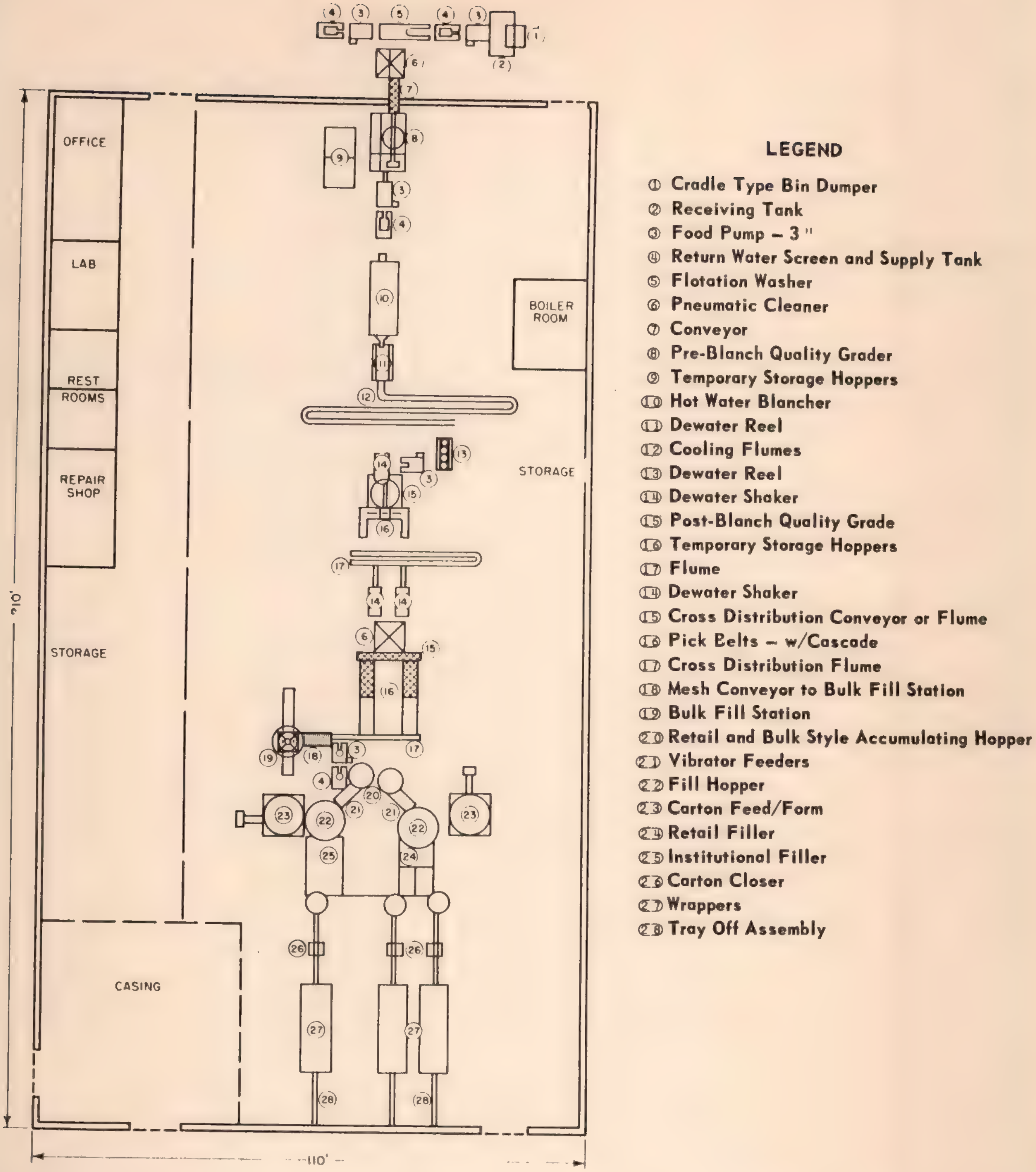

Figure 2. Lima Bean Freezing Plant Layout, Capacity 5 to 6 Tons per Hour. California, 1958.

The remaining sections of this report deal with analysis of the above operating stages and general cost components and a blending of the results in an analysis of the over-all costs of assembling and processing Lima beans for freezing.

ANALYSIS OF STAGE TECHNIQUES AND SYNTHESIS OF COST RELATIONSHIPS

Vining

Vining or shelling Lima beans in California usually involves one of two types of operation—mobile or stationary. In mobile vining a self-propelled unit operating as a combine harvester moves through the fields. Under the stationary system, the vines in the various fields of the area are cut and draper-loaded into trucks for transportation to the vining station which is normally located in the center of a production area.

Three methods of stationary vining—classified according to their degree of mechanization—were analyzed in relation to the amount of labor and equipment required at various rates of output and length of season.

In the least mechanized stationary operation considered—Method A—viners are arranged in a series of parallel pairs with approximately 6 feet between pairs. Vines are delivered by truck and dumped adjacent to the viner from where they are hand-forked onto the vine feed conveyor which moves them into the beater cylinder. Shelled beans drop through perforations in the revolving screen reel to a rotating canvas apron and are collected in cannery lug boxes from the viner delivery chutes. The lug boxes are picked up as they are filled and dumped by workers onto a main assembly conveyor which delivers them to a shaker-separator for additional trash separation. The beans pass through the shaker into a bulk-receiving container, which is transferred by lift truck to a delivery truck for delivery to the plant receiving station.1/ Additional cleaning or washing operations and icing may occur at this point. The vines are discharged from the viner screen reel onto a straw carrier which deposits

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1/ For bulk hauling, the bulk-receiving container may be picked up by the lift truck and dumped into the truck bed by operating a trip-lever device installed on the receiving hopper.

them in an ensilage trench. A standard 2-plow tractor equipped with a loader frame assembly is used to group vines for the fork workers and to spread or redistribute piles of vines collected in the ensilage trench.

In the second and more mechanized method studied—Method B—labor is reduced, and the rate of output per viner is increased approximately 20 per cent by the installation of power forks and vine feed regulators. The increased output per viner is primarily attributable to the vine feed regulator which results in a more even flow of vines to the beater cylinder and more effective effort on the part of the fork worker. With this additional equipment, one worker can supply vines to two viners rather than one and at a faster rate per viner. Other labor and equipment requirements are the same as for Method A.

In the third and most mechanized of the stationary vining operations—Method C—the equipment of Method B is supplemented with a side-delivery conveyor installed under each viner delivery chute. The beans thus are conveyed directly to the main assembly belt eliminating lug-handling labor.

In the mobile vining operation, self-propelled units with driver and attendant replace the vining station labor and equipment. A beater cylinder, screen reel, apron, and frame of a standard viner are mounted on a chassis with 4-wheel drive-and-steering and propelled by a tractor engine. A sway-bar mechanism keeps the reel and apron in a level position during operation. The viner cylinder and auxiliary equipment are operated by a standard 4-cylinder, air-cooled engine. The mobile viner moves through the field and picks up the vines—previously cut by the grower—by a specially designed drum which feeds them to a conveyor leading into the beater cylinder. The groundspeed of the viner is regulated to obtain optimum pickup and feed of vines to the beater cylinder. The shelled beans are collected on a side-delivery conveyor and elevated through a pneumatic cleaner to a collection hopper. The hopper is hydraulically elevated, and the beans are dumped periodically into a bulk-delivery truck for transfer to the receiving station of the plant.

Production Standards.--Production standards for labor and equipment were developed from operating and accounting record data for each of the four methods studied. These standards are related to capacity output rates measured in shelled weight. Standards for machine-paced jobs—hand and power forking, lug handling, and mobile unit operators and attendants—are directly related to the capacity rate of the viners. The average capacity output rate per stationary viner hour is 400 pounds with Method A, 475 pounds with Method B and

C, and 525 pounds per hour with mobile vining. Accordingly, the effective hand-forking standard--with one worker per viner--was estimated as 400 pounds per worker hour. The power-forking standard--with one worker per pair of viners--is equivalent to twice the viner capacity rate or 950 pounds per hour. Similarly, the lug-handling standard is 800 pounds per worker hour with Method A and 950 pounds for Method B. As one operator per mobile viner and one attendant for every two mobile viners are required, the standard for one mobile unit is 525 pounds per worker hour and 1,050 pounds for two units. Trucking standards for hauling vines from the field to vining station were converted to a shelled weight equivalent and related to the radius of haul. A standard of 880 pounds per truck hour, based on a maximum haul radius of 10 miles, was developed and used in this analysis. Standards for bulk-container attendant, lift-truck and tractor operation, and station cleanup are identical for each of the stationary vining methods and were estimated as 5,600, 20,000, and 4,000 pounds per man-hour, respectively. Field cleanup was estimated as 4,000 pounds per man-hour for all methods including mobile vining. Supervision for stationary operations consists of one crew supervisor and one general and field supervisor for all levels of output. One general supervisor is required for each operating group of 10 mobile viners.

These production standards are the basis for the estimated crew and equipment requirements summarized for the three stationary vining methods--Methods A, B, and C--in Table 1. With Method A, for example, an hourly production of 4,000 pounds of shell beans would require 10 forkers, 5 lug handlers, 2 cleanup workers, 1 lift-truck operator, 1 tractorman, 5 truckers for vine hauling, and 2 supervisors. Major equipment requirements in this example would be 10 viners complete with auxiliary equipment, a main assembly conveyor, 1 shaker-separator, 1 lift truck, and 1 tractor.

The crew and equipment requirements, as well as data on wage rates, unit investment costs for equipment, and other cost rates given in Table 1, are the basis for the estimates of variable costs, investment costs, and annual fixed charges given in Table 2. Variable costs--with a given hourly output rate--can be estimated by applying appropriate wage rates to crew requirements and adding the variable costs associated with equipment repair, maintenance, power, and fuel inputs. In the above example, labor costs are $28.32, and power, equipment repair and maintenance, and vine hauling are estimated as $27.64 per hour of operation. Total hourly variable cost necessary to achieve 4,000 pounds output per hour using Method A is the sum of the above estimates or $55.96.

TABLE 1

Stationary Vining--Crew and Equipment Requirements in Relation to Methods Used and Hourly Rate of Vining Output, California, 1958

Vining rate	Fork vines		Handle lugs		Attend fill	Operate lift	Tractor man	Clean-up	Haul vines	Supervise	Total crew requirements			Number of viners		Main conveyor		Lift truck	Tractor	Shaker separator
	Method																			
	A	B,C	A,B	C	A,B,C	A,B,C	A,B,C	A,B,C	A,B,C	A,B,C	A	B	C	A	B,C	A	B,C	A,B,C	A,B,C	A,B,C
pounds per hour shelled	number of workers a/													number		length in feet			number	
1,000	3	2	2	h/	i/	1	1	2	2	1	12	11	9	b/ 3	c/ 3	d/ 30	d/ 30	e/ 1	f/ 1	g/ 1
2,000	5	3	3			1	1	2	3	2	17	15	12	5	5	46	46	1	1	1
3,000	8	4	4			1	1	2	4	2	22	18	14	8	7	72	62	1	1	1
4,000	10	5	5			1	1	2	5	2	25	21	16	10	9	88	78	1	1	1
5,000	13	6	6			1	1	4	6	2	34	26	20	13	11	110	94	1	1	1
6,000	15	7	7		1	1	1	4	7	2	38	30	23	15	13	126	110	1	1	1
7,000	18	8	8		1	1	1	4	8	2	43	33	25	18	15	152	126	1	1	1
8,000	20	9	9		1	1	1	4	9	2	47	36	27	20	17	168	142	1	1	1
9,000	23	10	10		1	1	1	6	11	2	55	42	32	23	19	190	158	1	1	1
10,000	25	11	11		1	1	1	6	12	2	59	45	34	25	21	206	174	1	1	1
12,500	32	14	14		1	1	1	6	15	2	72	54	40	32	27	264	222	1	1	1
15,000	38	16	16		1	1	1	6	17	2	82	60	44	38	32	312	264	1	1	2
17,500	44	19	19		1	1	1	8	20	2	96	71	52	44	37	360	302	1	1	2
20,000	50	22	22		1	1	1	10	23	2	110	82	60	50	43	408	350	1	1	2
22,500	57	24	24		2	2	2	12	26	2	127	94	70	57	48	462	392	2	2	2
25,000	63	27	27		2	2	2	14	29	2	141	105	78	63	53	510	430	2	2	2
27,500	69	29	29		2	2	2	14	32	2	152	112	83	69	58	558	472	2	2	2
30,000	75	32	32		2	2	2	16	34	2	165	122	90	75	64	606	520	2	2	3
35,000	88	37	37		2	2	2	16	40	2	191	140	103	88	74	708	596	2	2	3

a/ Labor wage rates in dollars per hour and labor standards in pounds of shelled beans per man hour: Supervise and field, $2.25 per hour; 30,000 pounds per hour. Supervise crew, $1.60 per hour; 30,000 pounds per hour. Clean up, (field and station), $1.25 per hour; 4,000 pounds per hour. Haul vines (contract), $4.50 per hour; 880 pounds per hour. Operate tractor or lift truck, $1.61 per hour; 20,000 pounds per hour. Attend fill, $1.25 per hour; 5,600 pounds per hour. Handle lugs, $1.25 per hour; 800 pounds per hour with Method A and 950 pounds per hour with Method B. Fork vines, $1.25 per hour; 400 pounds per hour with Method A and 950 pounds per hour with Methods B and C.

b/ Method A: Viners are complete with viner unit including strawcarrier--$3,090; apron scraper--$33; vine shaker--$135; undercarrier separator--$117; feed conveyor--$460; 15-horsepower electric motor with reduction gear and drive assembly--$860; and freight and installation--$500. Total cost per viner is $5,215.

c/ Method B: Replacement costs are the same as for Method A except add to each unit a vine feed regulator--$365; and to each pair of viners a power fork hoist assembly--$807. Method C: Replacement cost identical to Method B except replace viner pea boxes with a side delivery conveyor installed beneath the viner delivery chutes. Converyor is 6 inches wide by 17 feet long and rides in a 2-inch channel equipped with V-type sideboards driven by viner reel--$280 each, installed.

d/ Main conveyor electrically driven, frame of angle and channel iron construction with 4-inch wood sideboards, and steel rollers 12 inches on center with return rollers to prevent sag. Cost of drive unit and conveyor frame is $347 for 1-horsepower motor and drive plus $10.30 per foot of conveyor. First 100 feet of conveyor is of 24-inch belting, next 100 feet is 18-inch belting, and 12-inch belting thereafter. Belting is 4-ply rubber cannery type where cost is estimated by the relation: $C_B = \$0.41\ (W)(L)$ where W is width of belt in inches and L is length in feet of conveyor.

e/ Standard 4,000-pound capacity gas driven lift truck, pneumatic tires--$5,775 each, delivered.

f/ Standard 2-plow tractor with 6-foot detachable loader frame assembly--$2,100 each, delivered.

g/ Sieve type shaker, 2 screen, o.d. 3' x 12', with 1/2-horsepower motor and drive--$1,460 each, custom built and installed.

h/ Lug handling not required with Method C.

i/ Lift truck operator attends fill for low output rates.

TABLE 2

Stationary Vining--Variable Costs, Replacement Costs, and Annual Fixed Charges in Relation to Methods Used and Hourly Rates of Output, California, 1958

Rate of vining output	Variable costs								
	Labor[a]			Power and maintenance[b]			Total		
	Method								
	A	B	C	A	B	C	A	B	C
pounds per hour shelled	dollars								
1,000	23.22	21.97	19.47	2.02	2.12	2.16	25.24	24.09	21.63
2,000	33.07	30.57	26.82	2.91	3.08	3.15	35.98	33.65	29.97
3,000	42.57	37.57	32.57	4.25	4.05	4.15	46.82	41.62	36.72
4,000	50.82	44.57	38.32	5.14	5.02	5.14	55.96	49.59	43.46
5,000	62.82	54.07	46.57	6.49	5.98	6.14	69.31	60.05	52.71
6,000	72.32	62.32	53.57	7.38	6.97	7.15	79.70	69.29	60.72
7,000	81.82	69.32	59.32	8.71	7.93	8.14	90.53	77.25	67.46
8,000	90.07	76.32	65.07	9.60	8.90	9.14	99.67	85.22	74.21
9,000	106.57	90.32	77.82	10.94	9.87	10.13	117.51	100.19	87.95
10,000	114.82	97.32	83.57	11.84	10.83	11.13	126.66	108.15	94.70
12,500	140.82	118.32	100.82	14.96	13.75	13.13	155.78	132.07	114.95
15,000	159.82	132.32	112.32	17.71	16.26	16.71	177.53	148.58	129.03
17,500	187.07	155.82	132.07	20.39	18.66	19.17	207.46	174.48	151.24
20,000	214.32	179.32	151.82	23.06	21.61	22.22	237.38	200.93	174.04
22,500	246.04	204.79	174.79	26.58	24.40	25.08	272.62	229.19	199.87
25,000	273.29	228.29	194.54	29.25	26.82	27.56	302.54	255.11	222.10
27,500	296.79	246.79	213.04	31.94	29.26	30.07	328.73	276.05	243.11
30,000	319.54	265.79	225.79	34.68	32.23	33.12	354.22	298.02	258.91
35,000	371.54	307.79	261.54	40.48	37.08	38.11	412.02	344.87	299.65

Rate of vining output	Replacement costs[c]								
	Equipment	Belting and miscellaneous	Total	Equipment	Belting and miscellaneous	Total	Equipment	Belting and miscellaneous	Total
	Method A			Method B			Method C		
pounds per hour shelled	dollars								
1,000	25,636	1,105	26,741	27,538	1,105	28,643	28,378	1,105	29,483
2,000	36,231	2,073	38,304	39,670	2,073	41,743	41,070	2,073	43,143
3,000	52,144	3,138	55,282	51,802	3,040	54,842	53,762	3,040	56,802
4,000	62,738	4,092	66,830	63,933	3,994	67,927	66,453	3,994	70,447
5,000	78,957	5,132	84,089	76,065	4,975	81,040	79,145	4,975	84,120
6,000	89,552	5,790	95,342	88,544	5,942	94,486	92,184	5,942	98,126
7,000	105,465	6,792	112,257	100,676	6,600	107,276	104,876	6,600	111,476
8,000	116,059	7,720	123,779	112,808	7,528	120,336	117,568	7,528	125,096
9,000	131,931	8,692	140,623	124,939	8,456	133,395	130,259	8,456	138,715
10,000	142,873	9,114	151,987	137,071	9,384	146,455	142,951	9,384	152,335
12,500	179,975	10,209	190,184	173,814	10,002	183,816	181,374	10,002	191,376
15,000	213,400	11,255	224,655	206,027	11,019	217,046	214,987	11,019	226,006
17,500	245,351	11,991	257,342	235,933	11,706	247,639	246,293	11,706	257,999
20,000	277,135	12,727	289,862	273,482	12,442	285,924	285,522	12,442	297,964
22,500	322,419	13,493	335,912	311,299	13,149	324,448	324,739	13,149	337,888
25,000	354,203	14,229	368,432	341,551	13,836	355,387	356,441	13,836	370,277
27,500	386,334	14,965	401,299	372,305	14,592	386,897	388,545	14,592	403,137
30,000	419,579	15,702	435,281	410,160	15,278	425,438	428,080	15,278	443,358
35,000	488,771	16,703	505,474	471,125	16,152	487,277	491,845	16,152	507,997

Rate of vining output	Annual fixed charges[d]								
	Equipment	Belting and miscellaneous	Total	Equipment	Belting and miscellaneous	Total	Equipment	Belting and miscellaneous	Total
	Method A			Method B			Method C		
pounds per hour shelled	dollars								
1,000	4,230	140	4,370	4,544	140	4,684	4,682	140	4,822
2,000	5,978	253	6,231	6,546	253	6,799	6,777	253	7,030
3,000	8,604	385	8,989	8,547	365	8,912	8,871	365	9,236
4,000	10,352	496	10,848	10,549	477	11,026	10,965	477	11,442
5,000	13,028	621	13,649	12,551	590	13,141	13,059	590	13,649
6,000	14,776	672	15,448	14,610	702	15,312	15,210	702	15,912
7,000	17,402	791	18,193	16,612	753	17,365	17,305	753	18,058
8,000	19,150	896	20,046	18,613	858	19,471	19,399	858	20,257
9,000	21,769	1,009	22,778	20,615	962	21,577	21,493	962	22,455
10,000	23,574	1,013	24,587	22,617	1,067	23,684	23,587	1,067	24,654
12,500	29,696	1,151	30,847	28,679	1,109	29,788	29,927	1,109	31,036
15,000	35,211	1,279	36,490	33,994	1,232	35,226	35,473	1,232	36,705
17,500	40,483	1,376	41,859	38,929	1,319	40,248	40,638	1,319	41,957
20,000	45,727	1,473	47,200	45,125	1,416	46,541	47,111	1,416	48,527
22,500	53,199	1,577	54,776	51,364	1,508	52,872	53,582	1,508	55,090
25,000	58,443	1,674	60,117	56,356	1,595	57,951	58,813	1,595	60,408
27,500	63,745	1,771	65,516	61,430	1,686	63,116	64,110	1,686	65,796
30,000	69,231	1,868	71,099	67,676	1,784	69,460	70,633	1,784	72,417
35,000	80,647	2,019	82,666	77,736	1,908	79,644	81,154	1,908	83,062

a/ For wage rates and crew requirements, see Table 1.

b/ Power requirements from Revised Cal. PUC Sheet No. 2891-E, Schedule PA-1, Agricultural Power, effective November 15, 1957. Costs are approximately $0.012 per horsepower hour. Operational maintenance and repairs estimated as 0.5 per cent of equipment replacement costs per 100 hours operations.

c/ For replacement costs of equipment units, see Table 1.

d/ Equipment: 16.5 per cent of equipment replacement cost includes depreciation--10 per cent; taxes--1 per cent; insurance--1 per cent; interest on investment--3 per cent (approximately 5 per cent of undepreciated balance); and fixed repairs and maintenance--1.5 per cent. Belting: Charged at 25 per cent of belting replacement cost. Miscellaneous: Charged at 10 per cent of replacement costs of miscellaneous equipment.

Replacement cost for any specified output rate is the sum of the equipment replacement costs and investment outlays. In the example, total outlay for major equipment items is estimated as $62,738. Supplemental outlays required for site construction, electric wiring installation, conveyor belting, spare motors, and repair parts are estimated as $4,092, giving a total outlay for an installation of this size of $66,830.

An annual fixed charge of 16.5 per cent of the major equipment cost of stationary vining includes: depreciation—10 per cent; taxes—1 per cent; insurance—1 per cent; interest on investment—3 per cent (or approximately 5.5 per cent of the undepreciated balance); and fixed repairs and maintenance—1.5 per cent. The annual fixed charge for site construction, electrical wiring, and spare parts was estimated as 10 per cent of replacement cost, while the annual fixed charge for belting was estimated as 25 per cent of belting replacement cost. Site rental costs are included. Applying these percentages to the equipment replacement costs developed in the above example gave an annual charge of $10,352 for the major equipment items and $496 for the supplemental equipment including $92 for site rental. Combining the separate charges gave a total annual fixed charge of $10,848 for a Method A installation with a 4,000-pound hourly production rate.

With mobile vining, the procedure used in estimating crew and equipment requirements and costs parallels that used in developing these estimates for stationary vining, with the exception of the percentages used in estimating the annual fixed charge. The annual fixed charge for equipment used in the mobile vining operation was estimated as 17 per cent of replacement cost. The higher percentage reflects a greater annual outlay for fixed repairs and maintenance attributable to higher costs of gasoline engine repair and overhaul and a higher rate of wear with the mobile equipment. Estimated crew and equipment requirements and costs for mobile vining are summarized in Table 3.

Total annual costs related to rate of vining output per hour and length of season were calculated by multiplying the hourly variable costs by the hours operated per season and adding the annual fixed charge. In the example given above—Method A, with 4,000 pounds output per hour of operation—variable costs totaled $55.96 per hour with an annual fixed charge of $10,848. For a season of 1,000 operating hours, total annual cost would amount to $66,808—$10,848 plus $55.96 multiplied by 1,000.

Calculations similar to those outlined in the preceding example can be made from the data in Table 2 and 3 for other hourly output rates and lengths

TABLE 3

Mobile Vining--Crew and Equipment Requirements and Costs California, 1958

Rate of vining	Crew requirements				Variable costs			Equipment requirements and costs			
	Operate and attend viners	Field cleanup	Field supervision	Total	Labor[a]	Fuel and maintenance[b]	Total	Viners	Service truck and welding unit	Total replacement cost[c]	Annual fixed charge[d]
pounds per hour					dollars			number		dollars	
1,000	3	1	1	5	8.00	2.61	10.61	2	1	26,200	4,454
2,000	6	1	1	8	12.50	5.11	17.61	4	1	50,200	8,534
3,000	9	1	1	11	16.50	7.61	24.11	6	1	74.200	12,614
4,000	12	1	1	14	21.50	10.11	31.61	8	1	98,200	16,694
5,000	14	1	1	16	24.50	11.36	35.86	9	1	110,200	18,734
6,000	17	2	1	20	30.25	13.86	44.11	11	1	134,200	22,814
7,000	20	2	2	24	37.00	16.36	53.36	13	1	158,200	26,894
8,000	23	2	2	27	41.50	19.02	60.52	15	2	184,400	31,348
9,000	26	2	2	30	46.00	21.62	67.62	17	2	208,400	35,428
10,000	29	2	2	33	50.50	24.22	74.72	19	2	232,400	39,508
12,500	35	3	2	40	60.75	29.42	90.17	23	2	280,400	47,668
15,000	42	3	3	48	73.50	35.92	109.42	28	2	340,400	57,868
17,500	48	4	3	55	83.75	41.33	125.08	32	3	390,600	66,402
20,000	56	4	4	64	98.00	48.08	146.08	37	3	450,600	76,602
22,500	62	5	4	71	108.25	53.48	161.73	41	3	498,600	84,762
25,000	69	5	5	79	121.00	60.39	181.39	46	4	560,800	95,336
27,500	75	6	5	86	131.25	65.99	197.24	50	4	608,800	103,496
30,000	83	6	5	94	143.25	72.99	216.24	55	4	668,800	113,696
35,000	96	7	6	109	166.25	85.90	252.15	64	5	779,000	132,430

[a] Wage rates: Operate and attend viners--$1.50 per hour; field cleanup--$1.25 per hour; and field supervision--$2.25 per hour.

[b] Fuel: Gasoline calculated at 3 gallons per hour per viner and truck at $0.21 per gallon. Oil estimated as $0.02 per hour per viner and truck. Variable maintenance and repair: Estimated as 0.5 per cent of equipment replacement costs per 100 hours operation. Includes mechanics' wages and supplies.

[c] Includes mobile viner and service truck with welding unit. Replacement costs: Viner--$12,000; and truck--$2,200.

[d] Includes depreciation--10 per cent; insurance--1 per cent; interest on investment--3 per cent; fixed repairs and maintenance--2 per cent; and taxes--1 per cent. The total is 17 per cent of replacement cost.

of season for each of the four methods considered. The results—for three selected length of season—are shown in Figure 3 for hourly output rates up to 30,000 pounds per hour. Figure 3 then provides a basis for selection of the most economical method of vining for the three selected lengths of season illustrated. Similar comparisons could be made for lengths of season different than those shown. Study of Figure 3 shows that in a 500-hour season, mobile vining is the low-cost method for rates of vining output below 6,000 pounds per hour, while Method C becomes the low-cost method for all hourly output rates above that level. For season of 1,000 and 1,500 hours, mobile vining becomes the low-cost method for all rates of output considered.

A useful generalization can be developed from total season costs like those given in Figure 3. This involves selection of the least-cost method with any given rate of output and length of season. The least-cost points so selected provide "planning costs" of the type previously defined and form the basis of a "planning equation." Such an equation for the vining operation[1] is given below and is represented graphically by the heavy dashed lines in Figure 3.

$$(1)\quad TSC_v = \$3,929 + \$2,633\ (R) + \$0.3691\ (H) + \$7.99\ (R)(H)$$

where

TSC_v is the total season cost of vining in dollars.
R^v is the rate of vining output in 1,000 pounds per hour.
H is the number of hours of vining operations during the season.

For any given rate of output and length of season, equation (1) can be used to estimate total season vining cost with efficient organization. As an illustration, consider a vining operation operating at the rate of 10,000 pounds per hour for a season of 1,000 hours. Total season cost for a vining

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[1] The equation shows the average relationship of annual costs to rate of vining output and length of season. It is computed to minimize the sum of the squared residuals between costs represented by the equation and the synthesized costs derived from Tables 2 and 3. The corrected multiple correlation coefficient is 0.9997. This indicates the equation gives a very close description of the synthesized costs representing an efficient vining operation. It is not, however, a statistical measure of the validity of these estimates. Similar results were obtained in calculations of other stage cost relationships developed in this study.

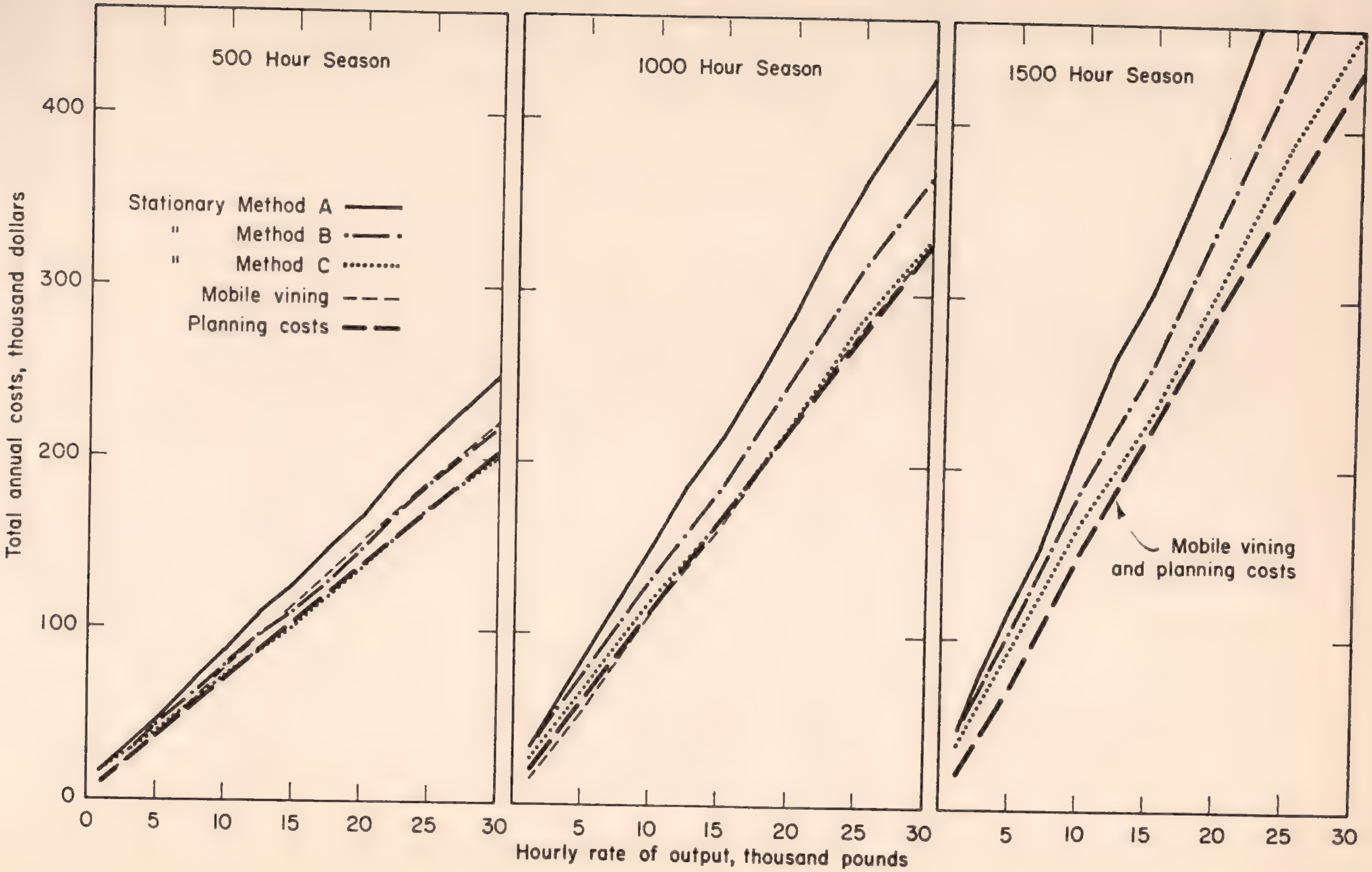

Figure 3. Total Annual Costs of Vining Lima Beans in Relation to Methods Used, Rate of Output, and Length of Season. California, 1958.

operation under these conditions is estimated by substituting for R and H in the above equation and solving, that is:

$$TSC_v = \$3,929 + \$\ 2,633\ (10) + \$0.3691\ (1,000) + \$7.99\ (10)(1000)$$
$$= \$3,929 + \$26,330 + \$369 + \$79,900 = \underline{\underline{\$110,528}}.$$

Viner to Plant Transportation

Costs of transporting Lima beans from the vining station to the plant receiving dock vary widely with respect to distance of haul, equipment capacities, and contractual arrangements. In California, Lima beans are hauled in bulk--by trailer or truck, or in tote bins.[1]

In most of the plants observed, the hauling was performed under contract with commercial trucking companies. Although the rates varied slightly among plants, most of the variation in transportation costs was due to the differences in tonnage per load and length of haul. To eliminate the effect of hauling charge differentials among areas, the 1957 schedule of rates listed in Minimum Rate Tariff No. 2 of the California Public Utilities Commission was used for establishing the costs used in this report. The rates in this schedule applicable to hauls of 20,000 pounds minimum weight--as shown graphically by the light, broken line in Figure 4--tend to level off as distance from the plant increases. A general expression relating truck-hauling cost per 1,000 pounds to distance hauled is shown by the solid line "smoothed" through the steps of Figure 4. This line, representing a generalized rate-distance relationship, is defined by the following expression:

$$(2)\quad THC = \$1.40\ (\log_{10} D)$$

where

THC is truck-hauling cost per 1,000 pounds of shelled Lima beans.
D is the distance from vining station to plant, expressed in logarithms (base 10).

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[1] Tote bins are wood containers approximately 4' x 4' x 4'.

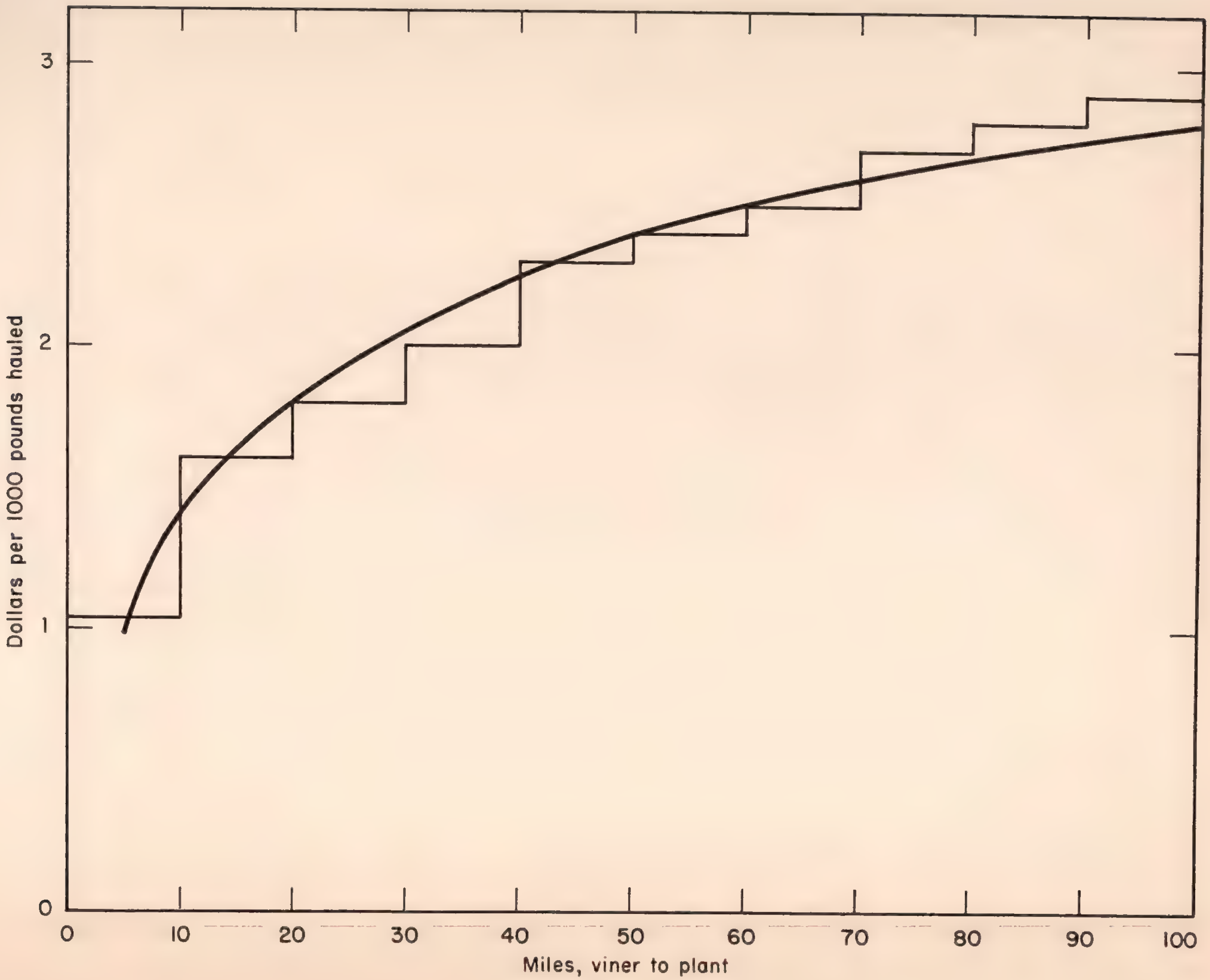

Figure 4. Commercial Trucking Rates Based on Minimum Loads of 20,000 Pounds (Shelled Basis) – Viners to Plant Hauling of Lima Beans Processed by Freezing, California, 1958.

Total annual costs can be estimated by multiplying equation (2) above by the annual volume of Lima beans vined (1,000 pounds of vining output per hour times the number of hours operated per season). This relation is given by the planning equation below and is graphically depicted in Figure 5.

$$(3)\quad TSC_H = \$1.40\ (\log D)\ (R)(H)$$

where

TSC_H is annual truck-hauling costs.
D is distance from vining station to plant, expressed in logarithms to the base 10.
R is 1,000 pounds of vining output per hour.
H is hours of vining operation per season.

This equation can be used to estimate the annual truck-hauling cost for any given rate of vining output, distance to plant, and hours operated per season. For example, the total annual cost of hauling for a vining operation of 10,000 pounds per hour, 20 miles from the plant, and operating over a season of 500 hours, is estimated by substituting these values for D, R, and H in equation (3) above and solving, that is:

$$\begin{aligned} TSC_H &= \$1.40\ (\log 20)(10)(500) \\ &= \$1.40\ (1.3010)(5{,}000) \\ &= \underline{\underline{\$9{,}107}} \end{aligned}$$

Estimated total annual hauling costs for a plant operating under the conditions assumed is $9,107. This result can be read directly from Figure 5, by entering the figure at 10,000 pounds, the appropriate season length, and distance hauled (point A) and reading off approximate total season hauling costs on the vertical scale (point B).

Receiving, Initial Cleaning and Initial Quality Grading

Two methods involved in the receiving, cleaning, and initial quality grading of Lima beans—bin handling and bulk handling—are considered.

With bin handling, the beans are normally subjected to an initial cleaning at a stationary vining site. After vining, the beans proceed on the main assembly conveyor through a pneumatic separator and are flumed to a series of straight-line washers equipped with destoning attachments. They are then

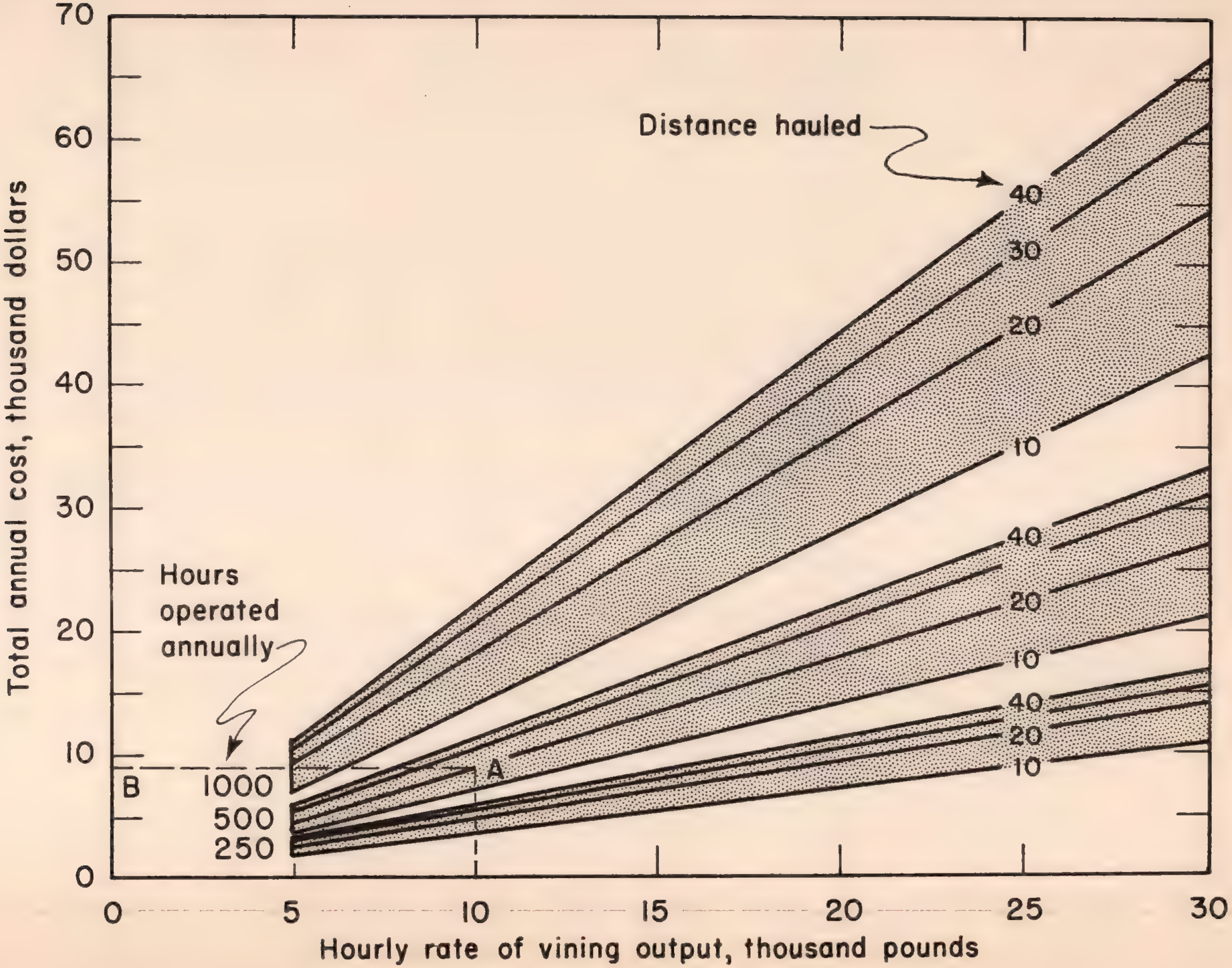

Figure 5. Total Annual Costs of Viners to Plant Transportation in Relation to Selected Distances and Vining Output Rates--Lima Beans Processed by Freezing, California, 1958.

conveyed into 4' x 4' x 4' tote bins. When filled, these bins are set aside by lift truck for icing down and transfer to a truck for delivery to the plant receiving station. Whether or not ice is added depends upon distance to the plant and on the possibility of temporary storage at the vining station or plant.

At the plant receiving station, and bins are set off by lift truck and either set aside to temporary storage or are placed directly on a cradle-type mechanical dump where they are emptied into receiving tanks mounted on a shaker frame assembly. The beans feed continuously from the receiving tank to a pump intake conveyor or flume where they are pumped through a dewatering shaker to quality graders situated on a raised platform. The quality grader separates the beans into maturity grades using the specific gravity principle. The higher grades float to the surface of a brine solution while the overmature or firms beans sink to the bottom. Each grade is discharged through separate discharge pipes. Normally, the higher quality beans continue to the blanching operation while the more mature beans are either conveyed to temporary storage for disposal as waste or to await their turn for further processing in a lower quality pack.

With bulk handling, the beans are loaded into the truck directly and do not require an intermediate container. In mobile vining operations, the beans are mechanically dumped from the collection hoppers of the individual viners and are hauled directly to the plant. In stationary vining operations, the beans may be cleaned at the vining site, as in bin handling, or sent directly to the plant. Icing down may occur with either mobile or stationary vining, depending upon the distance to the plant receiving station.

On arrival at the plant, the truckload is dumped in a receiving tank mounted on a shaker frame assembly and conveyed through the various cleaning and grading operations in the same manner as with bin handling.

Labor requirements with bin handling include a lift-truck operator at both field and plant locations and for operating and attending the cleaning, brining, and icing equipment. In bulk handling, the lift-truck operator at the plant receiving dock is replaced by a bulk-receiving attendant. With this exception, labor requirements of the two methods are identical.

The equipment requirements and unit equipment costs given in Table 4 are used to estimate the total investment cost with selected rates of output that are shown in Table 5. Annual fixed charges--and the percentages used in their computation--are also shown in Table 5. In addition, production standards for labor and wage information given in Table 5 are used to estimate the labor requirements and cost that are summarized therein.

TABLE 4

Equipment Requirements by Rate of Output and Method of Handling, Receiving Initial Cleaning and Quality Grading in Lima Bean Processing, California, 1958

Rate of output	Bulk handling																									
	Receiving tank[a]		Conveyor[b]	Shaker separator[c]	Conveyor[d]	Pneumatic separator[e]		Flume assembly[f]	Washers[g]		Conveyor or flume[h]	Pumping assembly[i]		Tubing[j]	Dewater shaker[k]	Briner platform[l]	Quality graders[m]		Pumping assembly[i]		Flume assembly[n]	Temporary storage tanks[o]		Walkways[p]	Icing equipment[q]	
pounds per hour	number	type	feet	number	feet	number	type	feet	number	type	feet	number	type	feet	number	square feet	number	type	number	type	feet	number	type	feet	number	type
5,000	1	B	10	1	8	1	A	3	1	A	10	--[r]	--	--	--	--	1	A	1	A	50	1 1	B C	35	1	A
10,000	1	C	10	1	8	1	B	14	2	A	20	1	A	78	2	450	2	A	[s]		104	2 1	A C	76	1	B
15,000	1 1	A B	20[1]	2	16[1]	1	D	27	2	C	28	1	B	78	2	450	2	C			120	3 1	A C	98	1	B
20,000	1 1	A B	20	2	16	1	E	27	2 1	B C	35	1	A	134	3	574	2 1	B C			120	4 1	A B	133	1	B
25,000	1 1	B C	20	2	16	2	C	28	1 2 1	A B C	45	1 1	A B	156	4	720	1 2 1	A B C			136	4 2 1	A B C	155	1	B
30,000	1 1	B C	30[2]	3	24[2]	2	D	28	4	C	45	1 1	A B	156	4	720	4	C			136	4 2 1	A B C	155	1	B

Rate of output	Bin handling																								
	Infield cleaning										Inplant operations														
	Conveyor[d]	Pneumatic separator[e]		Flume assembly[f]	Washers[g]		Conveyor[t]	Tote bins[u]	Icing equipment[q]		Lift truck[v]	Dumping station[w]	Receiving tank[a]		Conveyor[b]	Pumping assembly[i]		Tubing[j]	Dewater shaker[k]	Briner platform[l]	Quality graders[m]				
pounds per hour	feet	number	type	feet	number	type	feet	number		type	number			type	feet	number	type	feet	number	square feet	number	type			
5,000	8	1	A	3	1	A	15	24	1	A	1	1	1	B	10	--[r]	--	--	--	--	1	A			
10,000	8	1	B	14	2	A	23	48	1	C	1	1	1	C	10	1	A	78	2	450	2	A			
15,000	16[1]	1	D	27	2	C	23	72	1	C	1	1	1 1	A B	20[1]	1	B	78	2	450	2	C			
20,000	16	1	E	27	2 1	B C	31	96	1	C	2	2	1 1	A B	20	2	A	134	3	574	2 1	B C			
25,000	16	2	C	28	1 2 1	A B C	40	112	1	C	2	2	1 1	B C	20	1 1	A B	156	4	720	1 1 1	A B C			
30,000	24[2]	2	D	28	4	C	40	136	1	C	2	2	1 1	B C	30[2]	1 1	A B	156	4	720	4	C			

(Continued on next page)

Table 4 continued.

a/ Mounted on shaker frame for continuous feed. Custom manufacture of three types: Type A: 105 cubic feet, 1-horsepower motor, eccentric shaft, direct drive--$705, installed. Type B: 240 cubic feet, 3-horsepower motor, eccentric shaft, direct drive-$909, installed. Type C: 480 cubic feet, 4-horsepower motor, eccentric shaft, direct drive--$1,259, installed.

b/ Single conveyor with 3/4-horsepower motor and drive--$383, installed. 1/ Twin conveyor off single drive, 1-horsepower motor--$553, installed. 2/ Twin conveyor off single drive, 1-horsepower motor--$383, installed. Single conveyor with 3/4-horsepower motor sheared to third shaker separator--$383, installed.

c/ Custom-built trash separator, 12' x 3' with 3/4-horsepower motor and drive, capacity, 12,500 pounds per hour--$1,460, installed.

d/ Single conveyor with 3/4-horsepower motor and drive--$362, installed. 1/ Twin conveyor off single drive, 1-horsepower motor--$512, installed. 2/ Twin conveyor off single drive, 1-horsepower motor--$362, installed; and cross conveyor, 8' x 12", 3/4-horsepower and drive to deliver to pneumatic separator--$362, installed.

e/ Five Types: Type A: 18-inch intake, 3-horsepower, capacity 7,500 pounds per hour--$1,488, installed. Type B: 24-inch intake, 7-1/2-horsepower, capacity 10,000 pounds per hour--$2,698, installed. Type C: 30-inch intake, 7-1/2-horsepower, capacity 12,500 pounds per hour--$2,788, installed. Type D: 36-inch intake, 10-horsepower, capacity 15,000 pounds per hour--$3,050, installed. Type E: 42-inch intake, 10-horsepower, capacity 20,000 pounds per hour--$3,136, installed.

f/ Includes fluming, dewater reels, fittings, and waste water piping. For details on installed costs, refer to Appendix A, Table 1.

g/ Flotation washers with destoner attachment. Three types: Type A: 5,000-pounds per hour capacity--$2,789, installed. Type B: 6,500-pounds per hour capacity--$3,089, installed. Type C: 7,500-pounds per hour capacity--$3,389, installed.

h/ Conveyor for 5,000 rate 10' x 12"--$383, flumes thereafter. Flumes, fittings, waste or return water piping included. For unit costs refer to Appendix A, Table 1.

i/ Product pump assembly and intake tanks. Two types: Type A: 3-inch intake, capacity 12,000 pounds per hour--$695, installed. Type B: 4-inch intake, capacity 18,000 pounds per hour--$900, installed.

j/ Tube conveyors for product pumps--3-inch tubing of polyethylene and 4-inch tubing of aluminum. Elbows, tees, adaptors, valves, recirculating equipment included. For detailed costs refer to Appendix A, Table 1.

k/ Capacity is 8,000 pounds per hour, includes return water tank--$670, installed.

l/ Custom built, 5/16-inch safety plate, angle iron and black pipe construction, includes guard rails on stairway and platform. Platform is 10-feet above plant floor. Labor and materials cost--$3.40 per square foot.

m/ Types and capacities same as for washers (see g/). Installed cost is $200 less than washers since it does not include destoner equipment. Brine mix equipment, including tanks, brine density controller, and distribution system--$1,815, installed. One brine station supplies four quality graders.

n /Includes flumes, dewater reels, waste water tubing, elbows, tees, adaptors, and other fittings. See Appendix A, Table 1 for cost details.

o/ Capacity of storage is 8-hours at the rates indicated. Tanks are galvanized iron, sloped bottoms and sides. Three Types: Type A: 700 cubic feet, approximate capacity, 26,000 pounds--$785. Type B: 525 cubic feet, approximate capacity, 19,500 pounds--$665. Type C: 350 cubic feet, approximate capacity, 13,000 pounds--$550.

p/ Installed over temporary storage tanks, 5/16-inch safety plate, 2 feet wide with black pipe guard rails for stairs and walkways. Installation cost--$1.50 per lineal foot.

q/ Three types: Type A: Crusher with 3-horsepower motor, without blower, 40 cubic feet, galvanized iron tank mounted on warehouse truck, 4 scoop shovels--$1,048, installed. Type B: Same as Type A but includes 10-horsepower blower and ice delivery tubing--$2,052, installed. Type C: Same as Type A but includes additional tank assembly--$1,257, installed.

r/ Dashes indicate that with low output capacity this job does not apply.

s/ Blanks indicate that this job is performed by the pumping assembly crew.

t/ Designed as described in b/.

u/ Allows 8-hours of reserve storage at rates indicated. Capacity of tote bin is approximately 1,800 pounds, excluding ice. Bins cost $14, each.

v/ Standard type lift truck, 4000-pound capacity--$5,775, delivered.

w/ Cradle-type bin dumper, electrically driven 1/2-3/4 horsepower motor, capacity, 19,500 pounds per hour--$690, installed.

TABLE 5

Crew Requirements, Variable Costs, Equipment Replacement Costs, and Annual Charges by Rate of Output and Method of Handling--Receiving, Initial Cleaning, and Quality Grading in Plants Processing Lima Beans for Freezing, California, 1958

Rate of output	Bulk handling													
	Crew requirements[a]					Variable cost[b]			Replacement cost[c]			Annual fixed charge[d]		
	Receive	Attend cleaning equipment	Attend grading equipment	Icing and distribution	Total crew	Labor	Power and repairs	Total	Equipment	Belting	Total	Equipment	Belting	Total
pounds per hour	number of workers					dollars								
5,000	1	1	1	1	4	7.68	1.36	9.04	16,462	137	16,599	2,716	34	2,750
10,000	1	1	1	2	5	9.54	2.50	12.04	29,789	88	29,877	4,915	22	4,937
15,000	1	2	2	2	7	13.50	2.93	16.43	37,276	176	37,452	6,151	44	6,198
20,000	1	2	2	3	8	15.36	3.42	18.78	46,269	176	46,445	7,634	44	7,678
25,000	2	2	3	4	11	21.18	4.67	25.85	57,932	176	58,108	9,559	44	9,603
30,000	2	3	3	4	12	23.04	4.81	27.85	60,856	176	61,032	10,041	44	10,085
	Bin handling													
	e/	f/												
5,000	1	2	1	1	5	8.55	1.59	10.14	17,582	221	17,803	2,901	55	2,956
10,000	1	2	1	2	6	9.80	2.46	12.26	29,089	204	29,293	4,800	51	4,851
15,000	1	4	2	2	9	15.00	2.62	17.62	33,778	191	33,969	5,573	48	5,621
20,000	1	4	2	3	10	16.25	3.51	19.76	47,702	231	47,933	7,871	58	7,929
25,000	2	4	3	4	13	21.70	4.54	26.24	58,240	275	58,515	9,610	69	9,679
30,000	2	6	3	4	15	24.50	4.68	29.18	61,500	275	61,775	10,148	69	10,217

a/ Work standards and wage rates:

Job	Wage rate		Bulk handling	Bin handling
	Field	Plant		
	dollars		pounds per hour	
Receive bulk	--*	1.86	20,000	20,000
Receive bins	--	2.10	20,000	20,000
Attend cleaning equipment	1.25	1.86	10,000	10,000
Attend grading equipment	--	2.10	10,000	10,000
Distribution and ice	1.25	1.86	7,500	7,500

* Dashes indicate not applicable.

b/ Power costs estimated on basis of $0.025 per horsepower hour. Variable repair costs including wages and supplies for maintenance men estimated as 0.5 per cent of equipment replacement costs per 100 hours operation.

c/ Refer to Table 4 for delivered and installed prices of major equipment items.

d/ Equipment: 16.5 per cent of equipment replacement costs includes depreciation--10 per cent; taxes--1 per cent; insurance--1 per cent; interest on investment--3 per cent (approximately 5.5 per cent of undepreciated balance); and fixed repairs and maintenance--1.5 per cent. Belting: 25 per cent of belting replacement cost includes depreciation--20 per cent; taxes--1 per cent; insurance--1 per cent; and interest--3 per cent.

e/ Operates lift truck and bin dumper.

f/ Includes both field and plant location.

Total annual costs for four lengths of season are shown in Figure 6. The figure shows there is little difference in the total annual costs of the two methods. Selection of the method to use, therefore, will depend upon the preferences of the plant management concerned. Costs in this study are based on bulk handling.

As in the analyses of preceding operating stages, planning costs for the receiving, initial cleaning, and quality-grading stage are given in equation (4) below. The costs represented by this expression are graphically depicted by the heavy dashed line in Figure 6.

$$(4) \quad TSC = \$1,892 + \$320(R) + \$4.5882(H) + \$0.8494(R)(H)$$

where

TSC is total season cost in dollars for receiving, initial cleaning, and quality grading.
R is 1,000 pounds of output per hour.
H is hours of plant operation per season.

Blanching and Second Quality Grading

The blanching operation consists of subjecting the product to heat through the medium of hot water or steam, or a combination of both. A hot-water bath is the medium normally used in blanching Lima beans. The primary purpose of blanching is the partial prevention of enzyme activity associated with the production of "strong" flavors and discoloration.

The duration of the blanching treatment depends primarily on the temperature of the water bath and the size and firmness of the beans. At the temperature usually maintained--just below boiling--an exposure time of approximately 3 minutes for Baby Lima and 3-1/4 to 4 minutes for the Fordhook variety is required. Blanching equipment and service inputs (steam and water) requirements in this analysis were developed on the basis of a 4-minute exposure time.

The beans are flumed from the initial quality grade operation over a drain or dewater belt and into the blancher. The blancher consists of an outer tank that holds the blanch water through which the beans are conveyed in a perforated revolving drum or blanching reel by means of an inner spiral. Water is supplied at the discharge end of the unit and two steam inlet pipes are also provided. In this study it is assumed each blancher is equipped with a variable-speed transmission or drive and an automatic

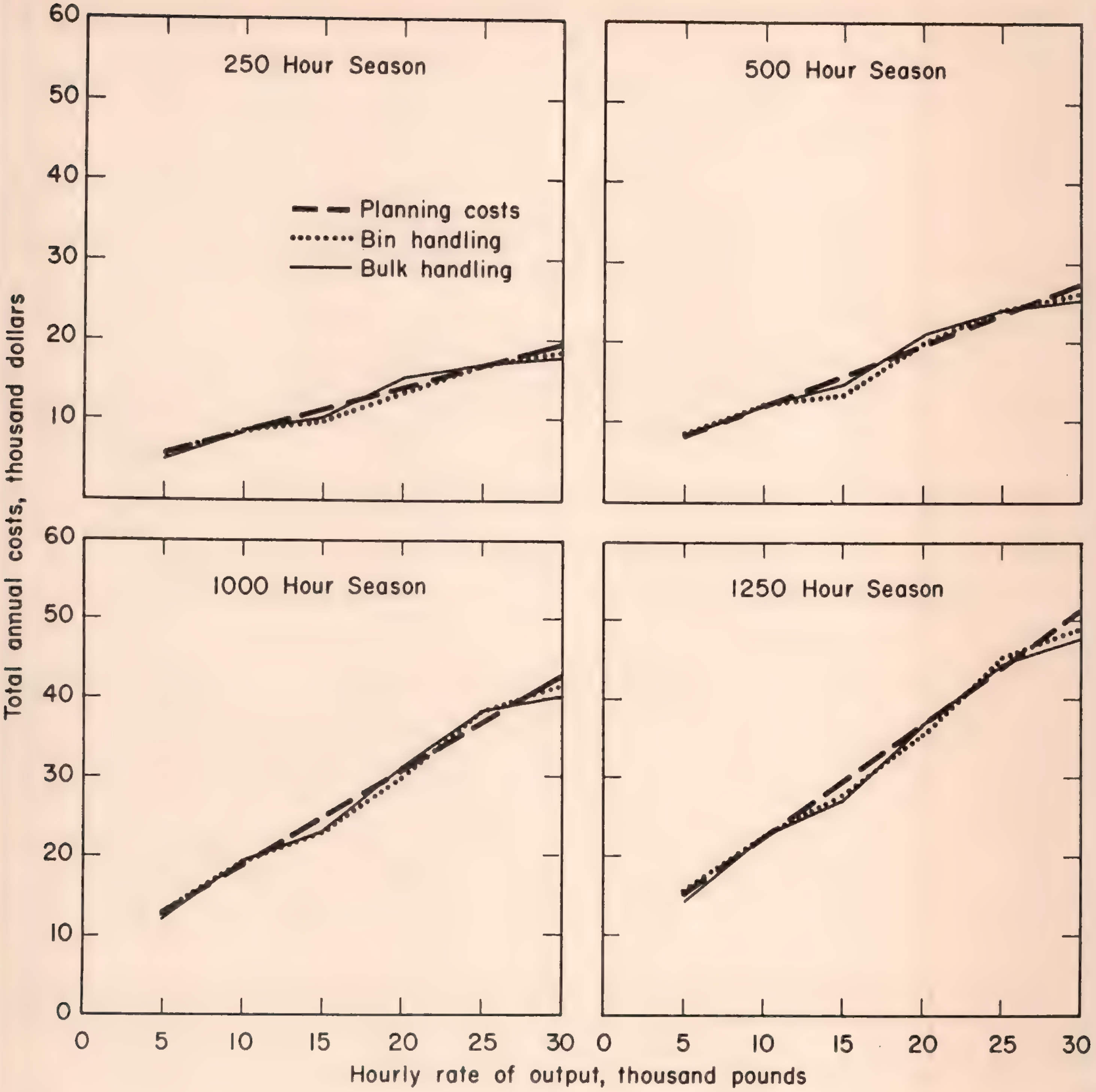

Figure 6. Total Annual Costs of Receiving, Cleaning, and Initial Grading in Relation to Methods Used, Rate of Output, and Length of Season. Lima Bean Freezing Plants. California, 1958.

temperature-control system to assist the operator in maintaining proper blanch temperatures and exposure times. Steam at 125 pounds per square inch pressure is furnished by boilers fired with forced draft natural gas burners.

In most of the operations studied, provision is made for a second or postblanch-quality grade operation. The postblanch-quality grading step is required when the quality of the product is such that the initial grading station cannot separate overmature and shriveled beans with enough selectivity to avoid grade losses. If the beans received are of generally high quality, however, initial grading may suffice, and the postblanch grading equipment may be used as a skimmer or bypassed entirely. Provision for postblanch grading is included in the equipment layout of plants synthesized in this report.

Labor requirements for this operating stage include attendants for the blanch, brine, and boiler equipment. Labor standards for these machine-paced jobs were developed from an analysis of plant record data and from direct observation of the job requirements in plants of different capacities.

Crew and equipment requirements and costs are summarized in Table 6. Production standards and the variable cost rates and equipment unit costs on which they are based—as well as the percentages used to compute annual fixed charges—are also given in Table 6. Variable costs and annual fixed charges given in Table 6—in relation to selected rates of plant output and hours operated per season—have been used in calculating total annual costs illustrated in Figure 7. Planning costs for blanching and second-quality grading are shown by the heavy dashed lines in Figure 7 and are given by equation (5) below.

$$(5)\quad TSC = \$1,293 + \$187(R) + \$5.6773(H) + \$0.2238(R)(H)$$

where

TSC is total season cost in dollars for blanching and second quality grading.
R is 1,000 pounds of output per hour.
H is hours operated per season.

Visual Inspection and Manual Quality Separation

While most overmature beans and defects are removed by mechanical brine separation and cleaning, maturity grading to a strict tolerance by this means is difficult because of insignificant differences—in some lots—in specific

TABLE 6

Crew and Equipment Requirements, Variable and Replacement Costs, and Annual Fixed Charges
for Blanching and Second Quality Grade Operation in Lima Bean Freezing Plants
California, 1958

Rate of output	Workers[a]	Variable costs			Equipment requirements												Replacement costs			Annual fixed charges		
		Labor	Power and repairs[b]	Total	Flume[c]	Conveyor[d]	Blanch equipment[e]		Steam data[f] Boiler	Steam	Heating surface	Cooling flume	Conveyor[g]	Second-quality grade[h]		By-pass conveyor[i]	Equipment[j]	Belting[k]	Total	Equipment[l]	Belting[m]	Total
pounds per hour	number	dollars			feet		number	type	h.p.	pounds	square feet	feet		number	type	feet	dollars					
5,000	3	6.30	0.74	7.04	17	10[1]	1	A	20[1]	690	108	50	10[1]	1	A	12" x 25'	13,703	221	13,924	2,261	55	2,316
10,000	3	6.30	1.02	7.32	20	10	1	C	27[2]	932	146	75	20[2]	2	A	15" x 25'	17,903	301	18,204	2,954	75	3,029
15,000	5	10.50	1.38	11.88	26	20[2]	2	B	50[3]	1,725	270	100	20	2	C	15" x 25'	24,747	350	25,097	4,083	88	4,171
20,000	5	10.50	1.60	12.10	28	20	2	C	54[4]	1,863	292	125	30[3]	2 1	B C	15" x 25'	28,503	400	28,903	4,703	100	4,803
25,000	7	14.70	2.18	16.88	28	30[3]	1 2	A C	74[5]	2,453	400	125	40[4]	1 2 1	A B C	18" x 25'	37,031	530	37,561	6,110	133	6,243
30,000	7	14.70	2.30	17.00	36	30	3	C	81[6]	2,794	437	150	40	4	C	18" x 25'	40,876	530	41,406	6,745	133	6,878

[a] Labor standards for each of the blanch, grader, and boiler room attendants are estimated as 10,000 pounds per hour. Wage rates for each of these jobs are $2.10 per hour.

[b] Power estimated as 2.5 cents per horsepower hour. Variable repairs estimated as 0.5 per cent of equipment replacement cost per 100 hours operation.

[c] Flume, galvanized iron, 20-guage, leading from temporary storage--$7 per foot, installed.

[d] Mesh conveyor, dewater, and distribution to blanchers. 1/ 10' x 12", 1 conveyor, 3/4-horsepower motor and drive--$432, installed. 2/ 10' x 12", twin conveyors, 3/4-horsepower motor off one drive--$659, installed. 3/ 10' x 12", 3 conveyors, 1-horsepower motor off one drive--$929, installed.

[e] Requirements based on 4-minute blanch, includes varispeed motor and drive and blanch temperature control assembly. Type A: 12-foot cylinder, capacity 6,400 pounds per hour--price estimated at $4,463, complete. Type B: 15-foot cylinder, capacity 8,000 pounds per hour--price estimated at $4,820, complete Type C: 18-foot cylinder, capacity 10,000 pounds per hour--price estimated at $5,182, complete.

[f] Includes 125-pounds-per-square-inch Scotch marine dryback boiler, trim and fittings, lagging, stack, forced draft natural gas burner, less steam piping and fitting. 1/ Boiler--$3,063, complete, installed. 2/ Boiler--$3,344, complete, installed. 3/ Boiler--$4,313, complete, installed. 4/ Boiler--$4,313, complete, installed. 5/ Boiler-$5,594, complete, installed. 6/ Boiler--$7,219, complete, installed.

[g] Mesh conveyors, each 12 inches wide, inclined 15 degrees. 1/ One conveyor, 3/4 horsepower motor and drive--$383, installed. 2/ Twin conveyors, 3/4 horsepower motor off one drive--$553, installed. 3/ Three conveyors, 1-horsepower motor off one drive--$655, installed. 4/ Two twin conveyors, two 3/4 horsepower motors and drives--$850, installed.

[h] Straight-line flotation type, complete with brine mix equipment, including tanks, brine density controller, and brine distribution piping. Type A: Capacity 5,000 pounds per hour--$4,404, installed. Type B: Capacity 6,500 pounds per hour--$4,704, installed. Type C: Capacity 7,500 pounds per hour--$5,004, installed.

[i] Mesh conveyor to by-pass second-quality grade, 1-horsepower motor and drive, drip pans. Motor and drive assembly and conveyor frame--$605 each, installed.

[j] Sum of replacement costs of individual equipment items.

[k] Belting cost estimated by expression: $0.41 (W)(L) where W is width of belt in inches and L is length of conveyor in feet.

[l] Estimated as 16.5 per cent of equipment replacement cost, includes depreciation--10 per cent; taxes--1 per cent; insurance--1 percent; interest on investment--3 per cent (approximately 5.5 per cent of undepreciated balance); and fixed repairs and maintenance--1.5 per cent.

[m] Estimated as 25 per cent of belting replacement cost, includes depreciation--20 per cent; taxes--1 per cent; insurance--1 per cent; and interest on investment--3 per cent.

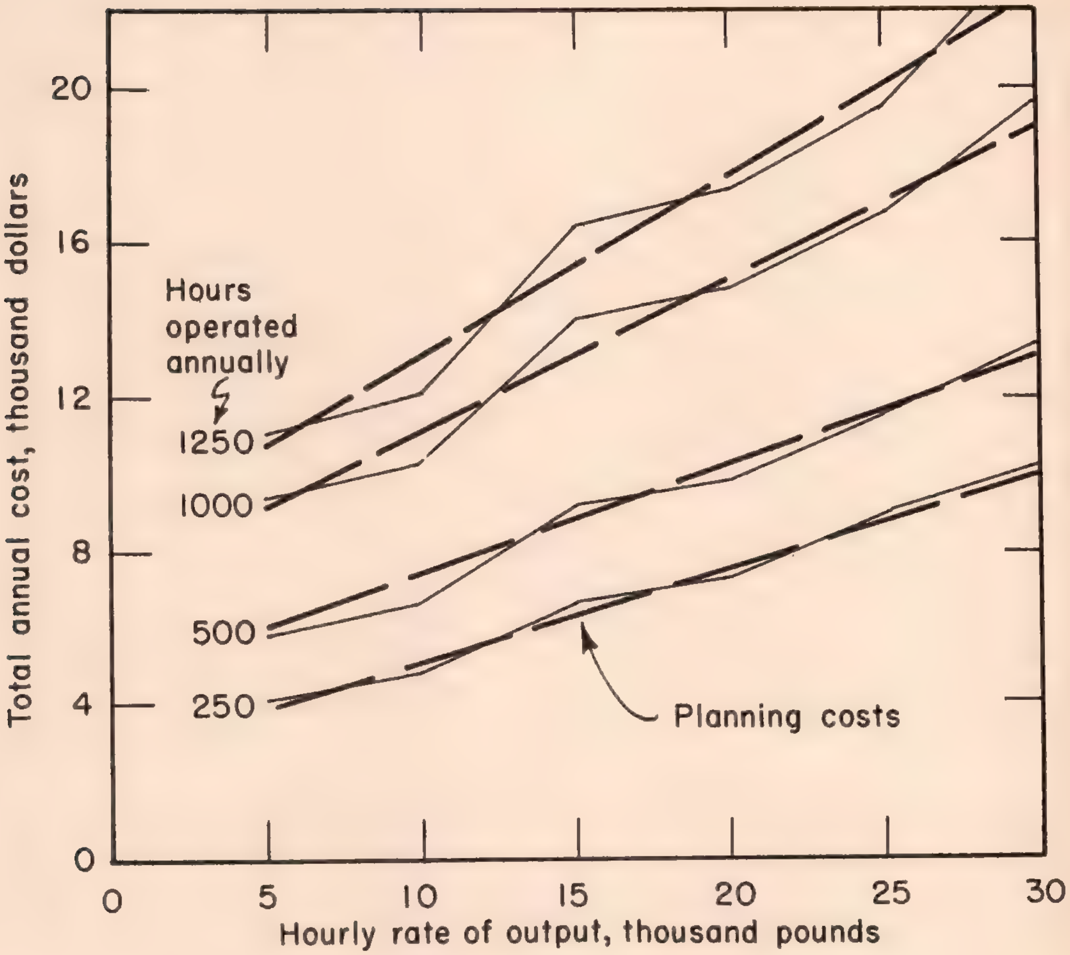

Figure 7. Total Annual Costs of Blanching and Second Quality Grading Operations in Processing Lima Beans for Freezing in Relation to Rate of Output and Length of Season, California, 1958.

gravity of green and overmature beans.[1] Consequently, quality separation by manual means is necessary for final inspection and removal of any overmature beans or defects that remain.

Beans are flumed directly from the second mechanical quality grading station to the sorting belts. These belts, with a few exceptions, are 24 inches wide and from 25 to 30 feet in length. A wire mesh belt (for dewatering) comprises the first section of the sorting belt from which the beans are deposited on a rubber cannery (or neophrene) belt moving in the same direction.[2] This arrangement results in a "cascade" effect which turns the beans over so both sides can be inspected with minimum effort by sorters stationed along the entire length of the belt, including the wire mesh section.

The amount of sorting labor required depends upon the volume of beans run per belt hour and the proportion of defects and overmature beans which must be removed. As visual inspection requires effort which cannot easily be measured in quantitative terms, direct work measurement techniques such as time and production studies are inappropriate for measuring the input of sorter labor. Accounting record data showing the number of sorters in relation to volume run per belt hour and pounds of grade-out were not available in the detail required. Furthermore, the number of beans, rather than their weight relative to volume per belt hour and proportion of grade-out, is a more relevant factor to consider in the measurement of sorting-labor inputs.

Because of the limitations of direct work measurement and the difficulty of obtaining adequate plant record data, an intermediate approach was used. Direct studies were made of the sorting operation in seven plants. The procedure used in the development of data for the analysis involved five major steps:

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[1] Defects include extraneous vegetable material, pieces, shrivels, sprouts, discoloration, and blemishes. For a more detailed discussion of grade determinants, refer to U.S. Standards for Grades of Frozen Lima Beans, 8th issue, April 16, 1957.

[2] Sorting tables or belts vary among plants in construction characteristics, width and length, but no significant differences in costs were detected. The inspection belts used in this study were 24" x 25', each with an estimated capacity of 7,000 per hour.

1. Samples of two pounds each were removed immediately prior to sorting.[1] At the same time, the number of the sorters employed on each inspection belt was recorded.
2. The volume of beans of each inspection belt at the time the sample was removed was estimated from the plant production tally.
3. A count was made of the total number of units in each sample. This included the total number of "green" beans in the sample as well as the number of grade-outs--overmature beans and defects.
4. "Manual grade-out percentage"--defined as the ratio of the number of beans including defects and overmature beans not meeting grade requirements to the total number of units in the sample--was computed and recorded.
5. A check was made with the U. S. Department of Agriculture or plant grade inspector to ascertain the grade and score of the finished product in each lot sampled.

The data obtained were made comparable and summarized according to volume run per belt hour, grade-out percentage, and number of sorters.[2] These data were then separated into subgroups reflecting small intervals in grade-out percentages. For each subgroup, the number of sorters were plotted against output rates per belt hour. Figure 8 shows these points for the 4 to 6 per cent grade-out category.

The wide scatter of points in Figure 8 suggests underutilization of sorting labor during certain periods in most of the plants studied. This was expected as workers idled during temporary stoppages in other parts of the

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1/ Approximately 300 samples were taken in each of the plants studied.

2/ On an equal weight basis, 100 Fordhook beans are on the average roughly equivalent to 283 Baby Lima beans. As observations were taken in plants processing both Baby and Fordhook varieties, the data obtained in the sampling procedure were placed on a comparable weight basis by converting one pound of Fordhook beans to an equivalent "count" basis by multiplying by 2.83. The conversion factor used was developed from count data in the samples described above and by numerous additional samples made available through the courtesy of the U. S. Department of Agriculture grade inspectors.

plant, and surplus labor provided for contingencies usually are assigned temporarily to the sorting operation even though not required by the work load there. In terms of the definition of work standards previously presented, an "efficiency standard" represents better than average--but not maximum--performance levels. The basis for selecting a sorting-labor standard is given in Figure 8. The solid line in the upper portion of the figure shows the average performance level of sorters at various rates of output per belt hour, while the dashed line indicates the maximum performance level observed. These two reference lines define the range of points considered in establishing the sorting standards in this analysis.[1] The line connecting the crosses in Figure 8 represents the sorting-labor standard finally derived for this particular manual grade-out percentage subgroup.

This procedure was followed for each of the manual percentage grade-out categories or subgroups considered.[2] A generalized expression derived from analysis of these data and relating the number of sorters to the rate of plant output per hour and manual grade-out percentage is summarized in the following equation:

$$(6) \quad N = 5.101 + 0.892(R) + 0.0656(R)(P)$$

where

N is the number of sorters required.
R is 1,000 pounds of plant output per hour.
P is manual grade-out percentage.

For any given rate of plant output and manual grade-out percentage, this equation can be used to estimate the number of sorters required with efficient organization. For example, the number of sorters required for a plant operating at the rate of 10,000 pounds per hour with a manual grade-out percentage of 5 per cent is estimated by substituting these values for (R) and (P) in the above equation and computing the value of N.

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[1] The points within the reference lines were fitted by the method of least squares.

[2] Subgroups of manual grade-out percentages considered were: 0.5 to 1 per cent, 1 to 2 per cent, 2 to 4 per cent, 4 to 6 per cent, 6 to 8 per cent, and 8 to 10 per cent.

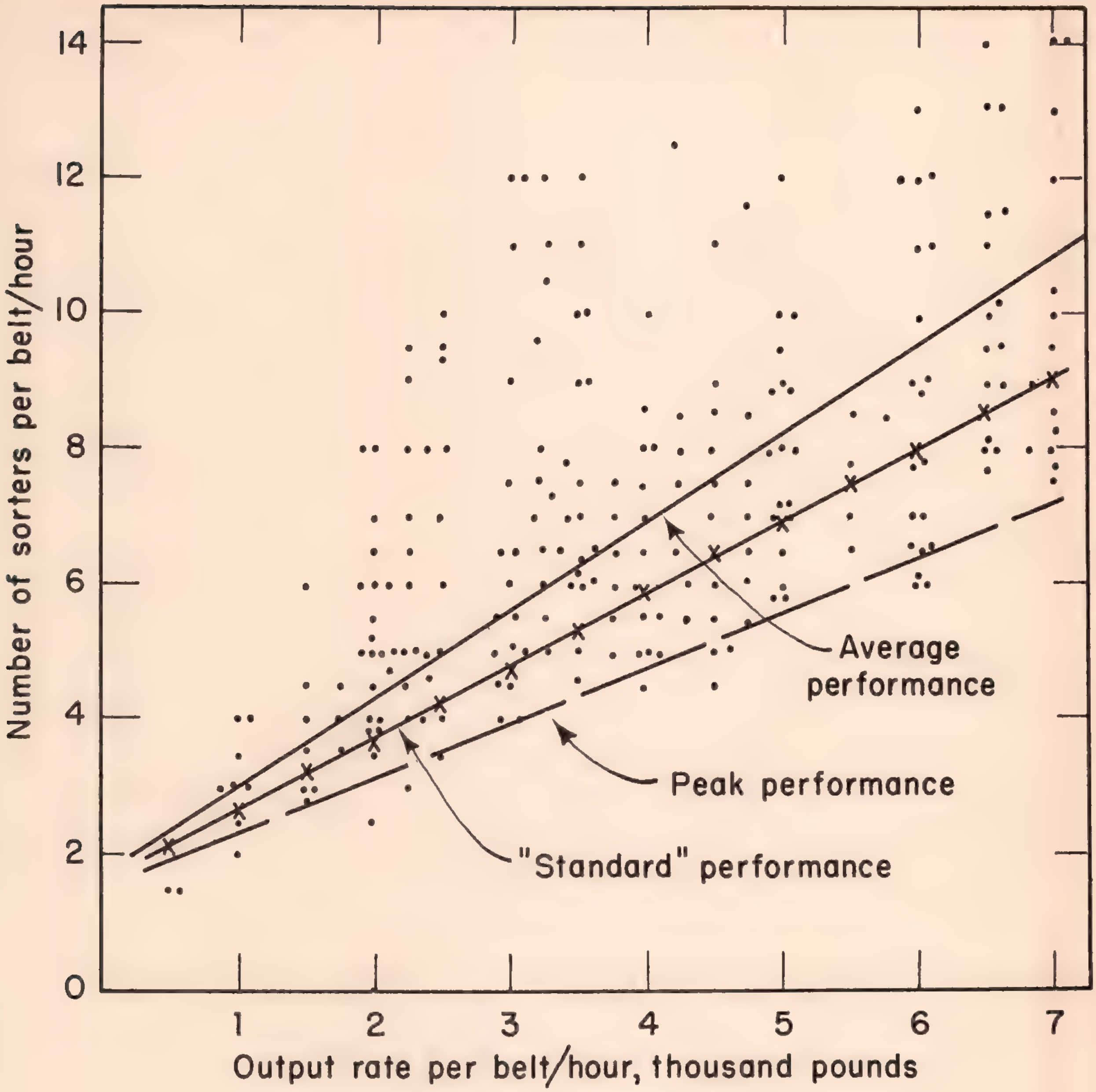

Figure 8. Sorting Labor Input Related to Output Per Belt Hour and 4 to 6 Per Cent Grade-Out Percentage in Lima Bean Freezing Plants, California, 1958.

That is:

$$N = 5.101 + 0.892(10) + 0.656(10)(5)$$

$$= 5.101 + 8.92 + 3.28 = 17.3 \text{ sorters.}$$

Eighteen sorters are required under the conditions assumed as fractional inputs are adjusted to the next whole number.

These relationships are set forth in graphic form in Figure 9. For the above example, the graph is entered at the point representing 10,000 pounds hourly output and 5 per cent grade-out count--point A in the figure--and the number of the sorters is read on the vertical scale at point B. As in the solution given by the equation, 18 sorters are required.

In order to use these relationships in forecasting sorter crew requirements, field estimates must be made of grade-out percentages. Grower "pay weight" samples may be used for this purpose. Reliable estimates of the efficiency of mechanical brine separation and cleaning equipment are also essential as a means of estimating the percentage grade-out count which must be manually graded, remembering that "percentage grade-out" refers to the percentage of overmature beans and defects on a count basis as distinguished from a weight basis. The sorting standards developed apply specifically to Grade A packs.

Sorting Costs

Hourly sorting-labor costs are obtained by multiplying the number of sorters required by the appropriate wage rate.[1] Table 7 lists equipment requirements and costs and hourly variable costs for selected rates of plant output. The data given in Table 7 can be used to compute estimated annual costs for the sorting operation for any given rate of plant output, length of season, and manual grade-out percentage. A generalized expression for the manual sort and quality separation stage based on such estimates is given in equation (7) below. This equation was derived by relating total season costs of the manual sort stage to rates of plant output and hours operated per season.

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[1] The number of sorters is stated in whole numbers, however.

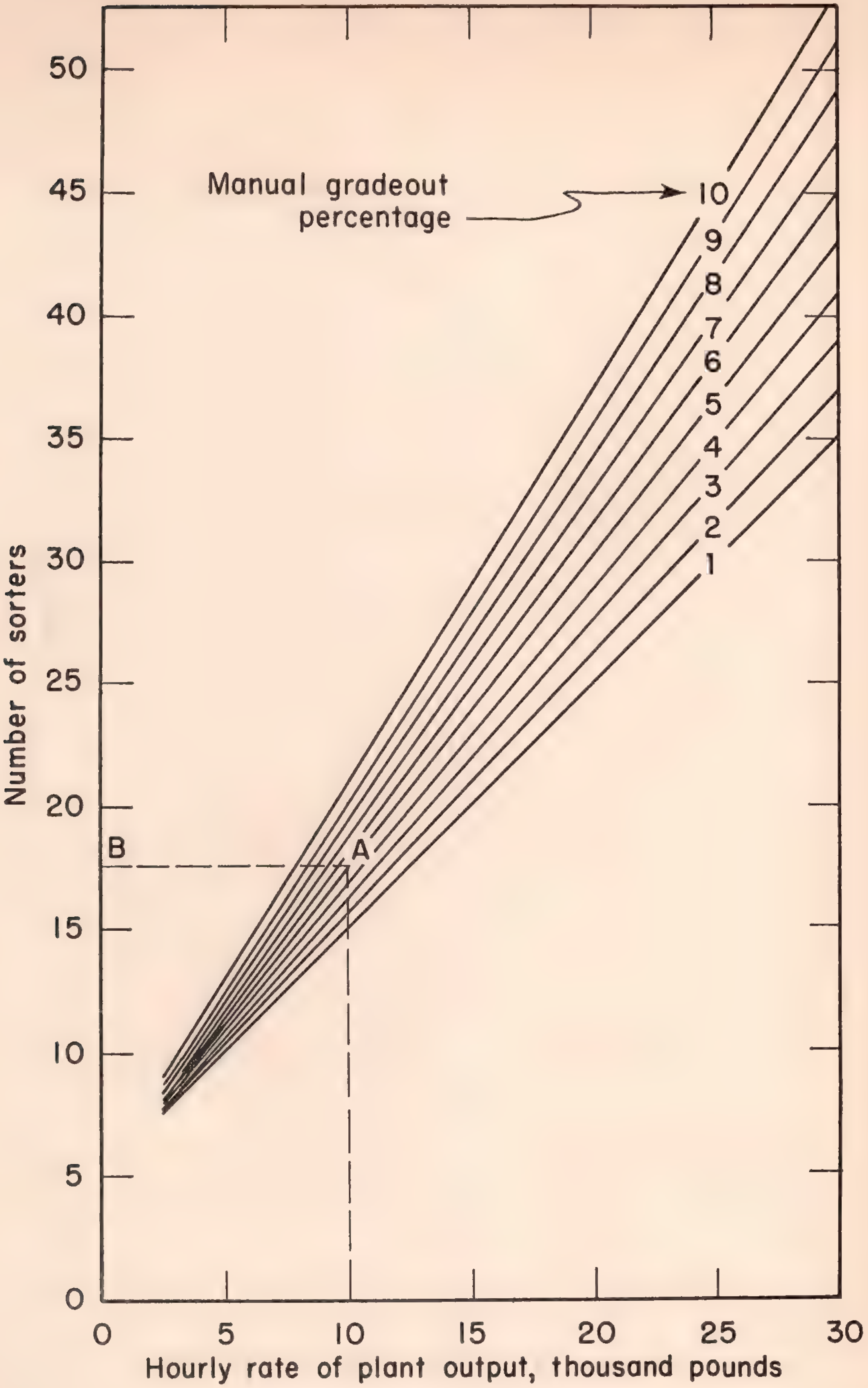

Figure 9. Labor Standards for Visual Inspection and Manual Quality Separation of Lima Beans Processed by Freezing, California, 1958.

TABLE 7

Visual Inspection and Manual Quality Separation Equipment Requirements, Replacement Cost, Annual Fixed Charge, and Variable Costs for Selected Hourly Rates of Output, Lima Beans, California, 1958

Rate of output	Equipment requirements		Replacement cost			Annual fixed charge			Variable costs per hour		
	Distribution flume[a]	Sorting tables[b]	Equipment	Belting	Total	Equipment[c]	Belting[d]	Total	Power and repairs[e]	Labor[f]	Total[g]
pounds per hour	feet	number	dollars								
5,000	45	1	1,004	369	1,373	166	92	258	0.09	16.10 + 0.56P	16.19 + 0.56P
10,000	65	2	1,833	738	2,571	302	185	487	0.18	23.60 + 1.11P	23.78 + 1.11P
15,000	93	3	2,718	1,107	3,825	448	277	725	0.27	31.10 + 1.67P	31.37 + 1.67P
20,000	93	3	2,718	1,107	3,825	448	277	725	0.27	38.60 + 2.22P	38.87 + 2.22P
25,000	114	4	3,554	1,476	5,030	586	369	955	0.35	46.10 + 2.78P	46.45 + 2.78P
30,000	135	5	4,390	1,845	6,235	724	461	1,185	0.44	53.60 + 3.33P	54.04 + 3.33P

a/ Includes low-grade and high-grade flumes for distribution to sorting tables and take-away at end of table. Flumes unseamed, galvanized iron--$7 per foot, installed.

b/ Includes 12½' x 24" neoprene belting; 12½' x 24" wire mesh dewater belt--"cascade"; 3/4-horsepower motor and drive; and tables equipped with drip pans. Installed costs: Motor and drive--$280 each; conveyor frame and rollers--$258 each table; drip pans--$100 each; and belting--$0.41 (W)(L) where W is width of belt in inches and L is length of conveyor in feet.

c/ Equipment: 16.5 per cent of equipment replacement cost includes depreciation--10 per cent; taxes--1 per cent; insurance--1 per cent; interest on investment--3 per cent (approximately 5.5 per cent of undepreciated balance); and fixed repairs and maintenance--1.5 per cent.

d/ Belting: 25 per cent of belting replacement cost includes depreciation--20 per cent; taxes--1 per cent; insurance--1 per cent; and interest on investment--3 per cent.

e/ Power estimated as 2.5 cents per horsepower hour. Variable repairs include wages of mechanics and supplies estimated as 0.5 per cent of replacement cost per 100 hours operation.

f/ Wage rates used are $1.685 per hour, straight time. Equation stating labor costs obtained by multiplying the expression for number of sorters required: $N = 5.101 + 0.892 (R) + 0.0656 (R)(P)$ by the corresponding hourly rate of output and wage rates.

g/ Labor costs plus variable power and repairs.

$$(7) \quad TSC = \$149 + \$32(R) + \$8.65(H) + \$1.51(R)(H) + \$0.1110(R)(H)(P)$$

where

TSC is total annual cost of visual inspection and manual quality separation in dollars.
R is 1,000 pounds of plant output per hour.
P is manual grade-out percentage.
H is hours operated per season.

The above equation can be used to estimate total annual sorting costs for any given size of plant (rate of output), length of operating season, and manual grade-out percentage. Total annual costs, represented by the above equation, are graphically depicted in Figure 10. The figure shows total annual costs in relation to hourly output rates and hours operated per season for manual grade-out percentages ranging from 5 to 10 per cent.

Packaging or Filling

Lima beans are packed in three styles of packages—retail, institutional, and bulk. The size of packages considered in this study are 10-ounce retail cartons, 2-1/2-pound institutional cartons, and 50 or 60-pound bulk bags or cases as these are the sizes most commonly packed. The retail style is normally packed to higher grade specifications than are the institutional and bulk styles. Although there is a selling price differential in favor of high grade retail packs, it is economical to pack lower grade institutional and bulk styles if the net returns are greater than the direct costs and expenses which could have been saved by their disposal as waste. If the lower grades are to be utilized, plants must be equipped with packaging facilities for handling these grades. This type of flexibility was accomplished in the plants observed by providing separate facilities for packaging retail, institutional, and bulk containers. The plants synthesized in this analysis are also equipped with separate packaging lines such that the capacity output rate of any given plant can be packed in any given style.

Variations among filling and packaging methods are primarily related to the type of freezing operation used. In California all plants observed used either tray-tunnel or plate-freeze methods that require packaging beans before freezing. Prefilling or prepackaging of beans before freezing—commonly called the "wet pack" method—involves a series of continuous operations. The beans are delivered to the fill stations by a fluming system serviced by product pumps. They pass through a dewater shaker to a pneumatic separator and into an

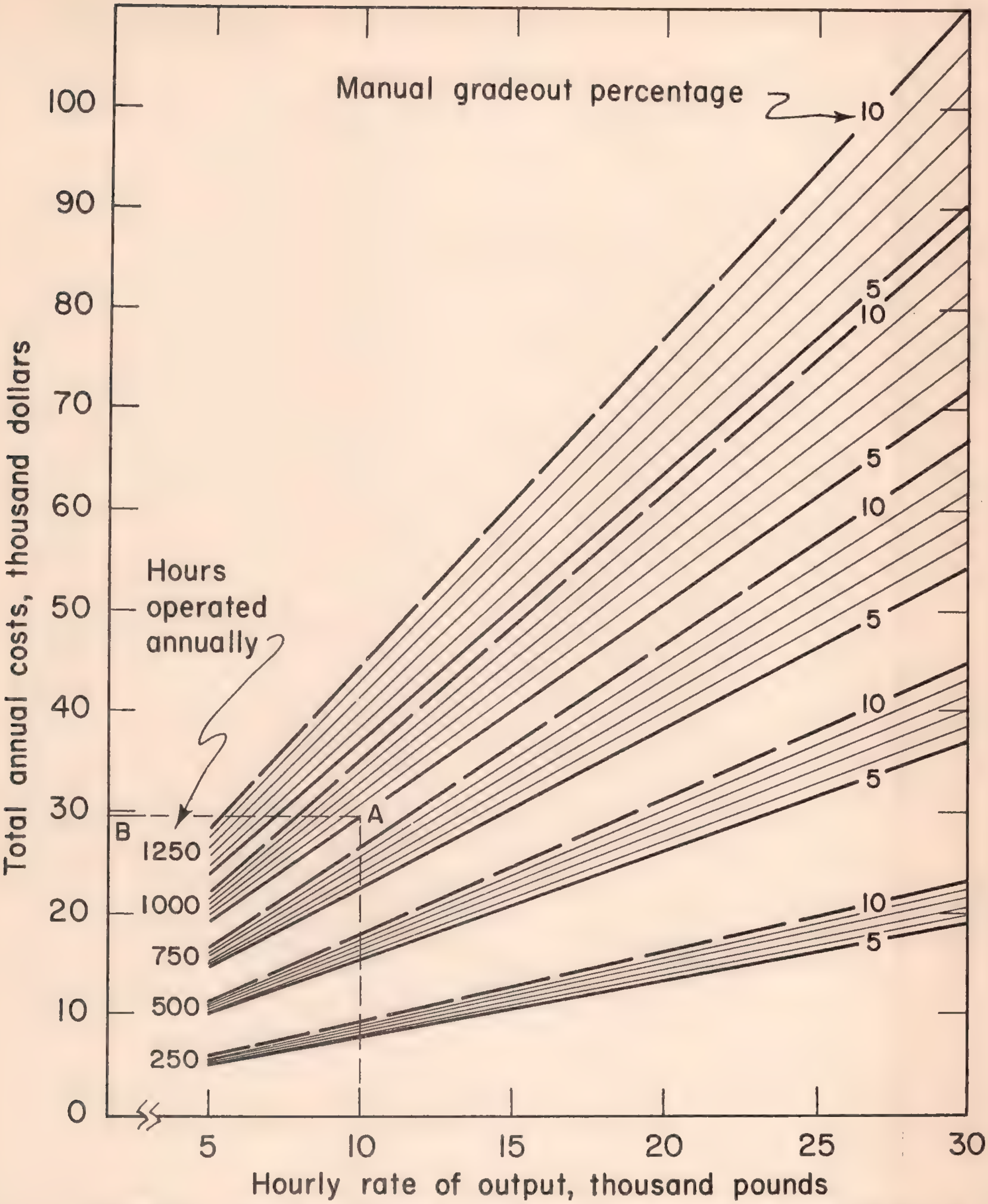

Figure 10. Total Annual Costs of Visual Inspection and Manual Quality Separation Lima Beans Processed by Freezing in Relation to Rate of Output, Length of Season, and Selected Manual Grade-Out Percentages, California, 1958.

accumulating hopper at each fill station. From the accumulating hopper, the beans are shaker fed to a mechanical filler for transfer to the appropriate container--retail, institutional, or bulk.

In the carton-fill operation, bundles of flat cartons are placed in the magazine that feeds the mechanical carton former. The cartons are filled as they move beneath cups mounted in a revolving filling cylinder, The filled cartons are segregated onto two conveyors by means of an interchanger. Workers stationed on each side of the conveyors inspect the filled cartons and remove cartons which are improperly formed or filled. After emerging from the automatic closing machines, the cartons are checkweighed and inspected for proper closure. The cartons continue through high-speed wrapping machines and are manually set off in trays and placed in skids or carts for transfer to the freezing tunnel or cabinet. Two types of carton-filling equipment are in general use for filling retail and institutional styles. The essential differences between these fillers involve the method of forming and closing the cartons.

In the bulk-fill operation, the beans feed from an accumulating hopper to trays passing beneath the filler on a powered roller conveyor. As the trays are filled, they move to a skate wheel take-off conveyor where they are loaded into skids for transfer to the freezing tunnel. Workers are required for supplying empty trays, attending the fill, setting off filled trays, and transferring the filled skids to the freezing tunnel. The trays are removed from the freezing tunnel and manually dumped into cluster-breaking equipment from which they are moved by a spiral conveyor to a bulk-fill station for packaging into 50-or 60-pound bags or cases. The bulk containers are filled, manually weighed, closed, stenciled, and set off to pallets for removal to the cold-storage warehouse.

Equipment arrangement, layout, and organization of the packaging stage will vary among plants according to local conditions and preferences of processors. The design reflected in the above description is a synthesis based on studies of actual plant layouts and on recommendations of processors and equipment manufacturers.

Equipment standards for the packaging stage were developed from studies of plant record data, production studies of packaging operation, and specifications of equipment manufacturers. These standards are summarized in Table 8. They were used in estimating the separate equipment requirements for each of the various styles of pack that are given in panels A, B, and C of the table. Requirements as to in-stage transportation equipment such as pumps, tubing and

TABLE 8

Equipment Requirements for Packaging Lima Beans for Freezing by Style of Pack and Selected Rates of Output California, 1958

Panel A--Retail packaging equipment								
Rate of output	Pneumatic separator a/		Accumulating hopper b/		Vibrator feeder c/	Filling equipment d/		Wrapping equipment e/
pounds per hour	number	type	number	type	number	number	type	number
5,000	1	A	1	A	1	1	A	1
10,000	1	B	1	A	1	1	B	2
15,000	1	D	1	B	2	2	A	2
20,000	1	E	2	A	2	1 1	A B	3
25,000	2	C	2	A	3	3	A	4
30,000	2	D	2	B	3	2 1	A B	4

Panel B--Institutional packaging equipment								
Rate of output	Pneumatic separator a/		Accumulating hopper b/		Vibrator feeder c/	Filling equipment f/		Wrapping equipment g/
pounds per hour	number	type	number	type	number	number	type	number
5,000	1	A	1	A	1	1	C	1
10,000	1	B	1	A	1	1	C	1
15,000	1	D	2	A	2	2	C	2
20,000	1	E	2	A	2	2	C	2
25,000	2	C	2	A	2	2	C	2
30,000	2	D	3	A	3	3	C	3

Panel C--Bulk packaging equipment						
Rate of output	Pneumatic separator a/		Tray fill assembly h/	Cluster separator i/	Spiral conveyor j/	Bag or case filler k/
pounds per hour	number	type	number			
5,000	1	A	1	1	1	1
10,000	1	B	1	1	1	1
15,000	1	D	2	2	2	2
20,000	1	E	2	2	2	2
25,000	2	C	3	3	3	3
30,000	2	D	3	3	3	3

Panel D--In-stage distribution equipment				
Rate of output	Pump assembly l/	Tubing m/	Flumes n/	Dewater reels o/
pounds per hour	number	feet		number
5,000	2	60	40	3
10,000	3	60	40	3
15,000	3	60	80	6
20,000	3	60	80	6
25,000	3	70	90	7
30,000	3	90	110	9

a/ Five types:
Type A: 18-inch intake, 3-horsepower motor, capacity 7,500 pounds per hour--$1,488, installed.
Type B: 24-inch intake, 7½-horsepower motor, capacity 10,000 pounds per hour--$2,698, installed.
Type C: 30-inch intake, 7½-horsepower motor, capacity 12,500 pounds per hour--$2,788, installed.
Type D: 36-inch intake, 7½-10 horsepower motor, capacity 15,000 pounds per hour--$3,050, installed.
Type E: 42-inch intake, 7½-10 horsepower motor, capacity 20,000 pounds per hour--$3,136, installed.

b/ Two sizes:
Type A: 45 cubic feet, conical or tetrahedral--$175.
Type B: 108 cubic feet, conical or tetrahedral--$358.

c/ Custom built, 3/4-horsepower motor, capacity, 10,000 pounds per hour--$475.

d/ Two types:
Type A: Retail filler, volumetric, with leased carton forming and closing attachment, capacity 7,500 pounds per hour--$4,065, installed; lease equipment--$13,279 payable in annual installments over 10-year period.
Type B: Retail filler, volumetric, with integrated carton forming and closing equipment, capacity 10,000 pounds per hour--wholly leased, $21,150 payable in annual installments over 10-year period.

e/ Retail wrapper, capacity 7,500 pounds per hour--$12,245, installed.

f/ Institutional filler, volumetric fill with leased carton closing and forming equipment, capacity 12,750 pounds per hour--$4,065, installed; lease equipment--$13,277 payable in annual installments over a 10-year period.

g/ Institutional carton wrapper, capacity 12,750 pounds per hour--$10,500, installed.

h/ Includes tray fill hopper, vibrator feed mechanism, powered roller conveyor (cleated for trays), 2-speed motor and drive assembly, take-off skate wheel conveyor. Custom built, capacity 10,000 pounds per hour--$1,823, installed.

i/ Custom made, 1-horsepower motor, capacity 10,000 pounds per hour--$1,200, installed.

j/ Each spiral conveyor 15 feet wide with 9-inch screw, enclosed, 1-horsepower motor and drive--$498 each, installed.

k/ Manually operated, includes hopper, spiral feed mechanism, shear gate, and hand lever, custom built--$672, installed.

l/ Pump assembly and intake tank, 3-inch pump, capacity 12,000 pounds per hour--$695, installed.

m/ Includes 3-inch polyethlyene tubing and fittings, flumes, dividers, chutes, waste water disposal tubes. For cost details refer to Appendix A, Table 1.

n/ G.i. unseamed construction 7-inch flumes--$7.00 per foot, installed.

o/ Dewater reels--$375, installed.

flumes used in distributing the product to the various fill stations are given in panel D of Table 8.

Labor standards for the jobs described earlier in this section were calculated from studies of plant record data and of actual operations in plants of different capacities. Crew requirements—along with the labor standards on which they are based—are summarized in Table 9.

The equipment and crew requirements given in Tables 8 and 9 are the basis for the estimates of variable and fixed costs summarized in Table 10. This involves conversion of packaging equipment requirements given in Table 8 to costs by applying estimated unit replacement costs to the number of equipment units required to achieve selected capacity output rates. Similarly labor costs with each capacity output rate considered were computed by applying appropriate wage rates to the estimated crew requirements given in Table 9.

Estimation of Packaging Costs

Variable Costs.—Estimation of annual variable costs for the packaging stage is complicated because they are not related to the output of a uniquely defined "product." Instead, output in this stage is defined in a multiple-product sense associated with different styles of pack or "product." Consequently, annual variable costs for this stage vary not only with hours operated per season and hourly capacity rates of plant output but also with the proportion packed in the various size containers. The estimation procedure may be simplified by determining the relationship between hourly variable costs of packaging each of the thred styles and hourly volumes of output. The initial step in this procedure involves plotting the variable cost points given in Table 10 against hourly rates of output for each of the three styles of pack as shown in Figure 11. The figure indicates that as hourly rate of output increases, increasing hourly variable costs with a given style of pack may be represented by a straight line passing through the origin. In this case, hourly unit cost per pound—for packaging each style of pack—is constant at all capacityrates of filling and is independent of the scale of operations. Average unit costs per hour—based on the points in Figure 11—are $24.730 per 1,000 pounds packed in retail cartons, $14.480 per 1,000 pounds packed in institutional cartons, and $4.590 per 1,000 pounds packed in bulk bags or cases. Total variable packaging costs per season can be estimated by applying the unit costs

TABLE 9

Crew Requirements for Packaging Lima Beans for Freezing by Style of Pack and Selected Rates of Output, California, 1958

Rate of output	Retail packaging crew requirements a/							
	Feed cartons	Attend fill	Check weight	Inspect cartons	Tray off	Supply skid and tally	Supply materials	Total crew
pounds per hour	number of workers							
5,000	b/	1	1	1	2	1	c/	6
10,000	1	1	2	2	4	1	1	12
15,000	1	2	3	3	5	2	1	17
20,000	2	2	4	4	7	2	2	23
25,000	2	3	4	5	8	3	2	27
30,000	2	3	5	5	10	3	3	31

Rate of output	Institutional packaging crew requirements d/							
	Feed cartons	Attend fill	Check weight	Inspect cartons	Tray off	Supply skid and tally	Supply materials	Total crew
pounds per hour	number of workers							
5,000	b/	1	1	1	1	1	c/	5
10,000	1	1	2	2	2	1	1	10
15,000	1	2	3	3	3	2	1	15
20,000	2	2	4	4	4	2	2	20
25,000	2	3	4	5	4	3	2	23
30,000	2	3	5	5	5	3	3	26

Rate of output	Bulk packaging crew requirements e/								
	Feed trays	Attend fill	Truck skids	Dump to cluster breaker	Operate fill and check weight	Set off bags or cases	Supply materials	Total crew	Attend distribution f/
pounds per hour	number of workers								
5,000	g/	1	2	1	2	1	1	8	1
10,000	1	1	2	2	4	2	1	13	1
15,000	1	1	2	2	6	2	1	15	1
20,000	2	2	2	3	6	3	1	19	1
25,000	2	2	4	3	8	3	2	24	1
30,000	3	3	4	4	10	4	2	30	1

a/ Labor production standards and hourly wage rates, 10-ounce retail cartons. Standards: Feed cartons, attend filler, supply and truck skids, and supply packaging materials--19,500 cartons per man hour; check weight and inspect cartons--9,750 cartons per man hour. Wage rates: Feed cartons, attend fill, check weight, and inspect cartons--$1.69 per hour; all other jobs--$1.86 per hour.

b/ Cartons fed by filler attendant.

c/ Materials supplied by skid supply man.

d/ Labor production standards and hourly wage rates, $2\frac{1}{2}$-pound institutional cartons. Standards: Feed cartons, attend filler, and supply packaging materials--5,100 cartons per man hour; check weight, inspect cartons, and tray off--2,550 cartons per man hour; supply and truck skids--8,000 cartons per man hour. Wage rates: Same as for retail packaging jobs.

e/ Labor production standards and wage rates, 50-pound bulk bags, cases, or trays. Standards: Feed trays for loose fill and attend tray filler--200 trays per man hour; supply and truck skids--400 trays per man hour; supply packaging materials and stencil--400 bags or cases per man hour; operate fill and check weight, set off filled containers--50 bags or cases per man hour. Wage rates: For all jobs--$1.86 per hour.

f/ Attend pumps, flumes, and product flow of in-stage distribution system--30,000 pounds per man hour. Wage rate: $1.86 per hour.

g/ Feed trays job done by bulk filler operator.

TABLE 10

Variable Costs, Equipment Replacement Costs, and Annual Fixed Charges for Packaging Lima Beans for Freezing by Style of Pack and Selected Rates of Output California, 1958

Pate of output	Retail packaging costs									
	Variable costs				Equipment replacement costs			Equipment Annual fixed charges		
	Labor[a]	Cartons, wraps[b]	Power and repairs[c]	Total	Purchase[d]	Lease[e]	Total	Purchase[f]	Lease[g]	Total
pounds per hour	dollars									
5,000	10.63	113	1.83	125.46	18,653	13,277	31,930	3,078	1,328	4,406
10,000	21.24	225	2.59	248.83	28,248	21,150	49,398	4,661	2,115	6,776
15,000	30.01	337	3.68	370.69	37,388	26,554	63,942	6,169	2,655	8,824
20,000	40.63	450	4.58	495.21	46,326	34,427	80,753	7,644	3,443	11,087
25,000	47.71	563	6.17	616.88	69,346	39,831	109,177	11,442	3,983	15,425
30,000	54.96	675	6.31	736.27	66,201	47,704	113,905	10,923	4,770	15,693
	Institutional packaging costs									
		i/								
5,000	8.77	63	1.73	73.50	16,728	13,279	30,007	2,760	1,328	4,088
10,000	17.53	126	1.75	145.28	17,938	13,279	31,217	2,960	1,328	4,288
15,000	26.30	190	3.50	219.80	33,456	26,558	60,014	5,520	2,656	8,176
20,000	35.06	253	3.50	291.56	33,616	26,558	60,174	5,547	2,656	8,203
25,000	40.29	315	3.68	358.97	36,056	26,558	62,614	5,949	2,656	8,605
30,000	45.69	378	5.25	428.94	51,820	39,837	91,657	8,550	3,984	12,534

Rate of output	Bulk packaging costs					
	Variable costs				Equipment replacement costs[d]	Annual fixed charge[f]
	Labor[a]	Containers[h]	Power and repairs[c]	Total		
pounds per hour	dollars					
5,000	14.88	13	0.60	28.48	5,031	830
10,000	24.18	26	0.66	50.84	5,061	835
15,000	27.90	39	1.19	68.39	5,931	979
20,000	35.34	52	1.26	88.60	6,891	1,137
25,000	44.64	64	1.73	110.37	11,680	1,927
30,000	55.80	77	1.80	134.60	12,904	2,129
	In-stage distribution costs					
5,000	1.86	j/	0.29	2.15	2,997	495
10,000	1.86		0.35	2.21	3,800	627
15,000	1.86		0.50	2.36	5,310	876
20,000	1.86		0.50	2.36	5,310	876
25,000	1.86		0.54	2.40	5,782	954
30,000	1.86		0.61	2.47	6,826	1,126

a/ Calculated from crew requirements and wage rates given in Table 9.

b/ 10-ounce retail cartons: 5-1/4" x 1-3/8" x 4", 0.015 solid bleach sulphate. Requirements calculated at capacities indicated plus 2 per cent waste allowance. Price estimated at $9.77 per 1,000. 10-ounce overwraps: Five-color print. Price estimated at $4.02 per 1,000.

c/ Power estimated at 2.5 cents per horsepower hour. Variable repairs estimated as 0.5 per cent of equipment cost per 100 hours operation.

d/ Cost of replacing all equipment, excluding lease items. For unit costs of separate items, refer to Table 8.

e/ Rental price of lease filling equipment items. Ten-year lease cost calculated at current prices.

f/ Calculated as 16.5 per cent of equipment replacement cost, including depreciation--10 per cent; taxes--1 per cent; insurance--1 per cent; interest on investment--3 per cent (approximately 5.5 per cent of undepreciated balance); and fixed repairs and maintenance--1.5 per cent.

g/ Annual rental price.

h/ 50-pound bags: Multiwall, 1/40 wax, 6-inch tuck-in sleeve, 2/60 wet strength, plain--price estimated at $128.80 per 1,000. 50-pound cases: Price estimated at $128.80 per 1,000 pounds.

i/ 2-1/2 pound institutional cartons: 9-1/2" x 5-1/4" x 2-1/2", 0.020 solid manila. Requirements calculated at capacities indicated plus 0.5 per cent waste allowance. Price estimated at $23.71 per 1,000. 2-1/2 pound overwraps: Two-color print. Price estimated at $7.54 per 1,000.

j/ Blanks indicate that container costs do not apply.

given above to the total season volume packed in each style.[1] Annual variable costs, calculated on this basis, are given in equation (8) below.

$$(8) \qquad TVC = \$24.730(H_r)(R) + \$14.480(H_i)(R) + \$4.590(H_b)(R)$$

where

TVC is total variable costs of packaging per season in dollars.
R is 1,000 pounds of plant capacity output per hour.
H_r is number of hours operated, retail style.
H_i is number of hours operated, institutional style.
H_b is number of hours operated, bulk style.

This equation can be used to estimate annual variable packaging costs for any proportion of total season volume that is packed in retail, institutional, or bulk styles.[2]

Annual Fixed Cost

The annual fixed charges of packaging equipment--for selected capacity output rates--are given separately for each style of pack in Table 10. The total annual fixed cost of packaging equipment required for handling a given plant capacity is the sum of the annual fixed charges necessary to achieve that rate of output in either of the three styles. A generalized expression showing how total annual fixed cost varies with the size of plant--measured in capacity rates of plant output--is given in equation (9) below.

$$(9) \qquad TFC = \$4{,}345 + \$856(R)$$

where

TFC is total annual fixed cost of packaging in dollars.
R is 1,000 pounds of plant capacity output per hour.

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[1] Total season volume in each style container is calculated by multiplying the number of hours spent per season in packaging each style by the capacity rate of plant output per hour.

[2] For any given hourly rate of plant output, $\frac{H_r}{H}$, $\frac{H_i}{H}$, and $\frac{H_b}{H}$, are the proportions of total season volume packed in retail, institutional, and bulk styles, respectively.

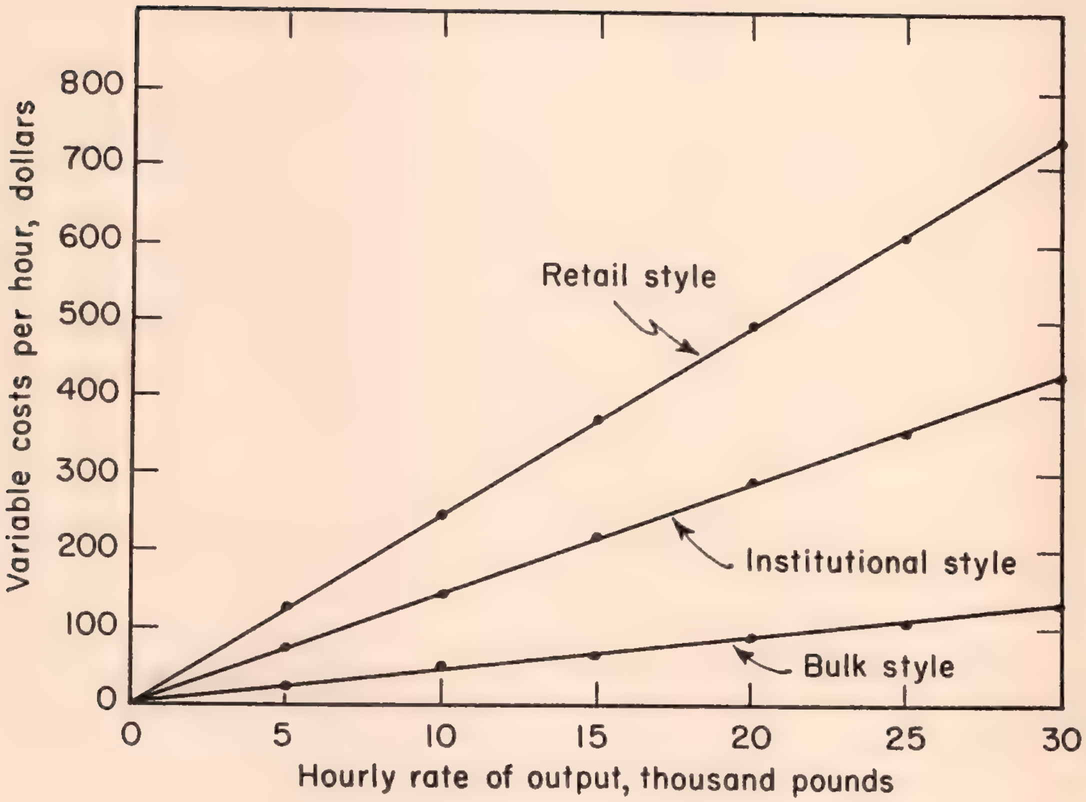

Figure 11. Relation of Hourly Variable Packaging Costs to Hourly Rates of Output in Lima Bean Freezing Plants Equipped to Package Retail, Institutional, and Bulk Containers, California, 1958.

Total Annual Packaging Costs

Total annual packaging costs—for any given plant capacity and length of operating season—is the sum of the corresponding annual fixed and variable cost components. The generalized total season or "planning" cost equation for plants packaging any combination of retail, institutional, or bulk styles is obtained by combining equations (8) and (9) above and is given in the expression below:

$$(10)\ TSC = \$4{,}345 + \$856(R) + \$24.730(H_r)(R) + \$14.480(H_i)(R) + \$4.590(H_b)(R)$$

where

TSC is the total annual cost of packaging Lima beans and (R), (H_r), (H_i) and (H_b) are as defined in equation (1) above.

For any given length of season, proportions packed in the various styles, and rate of plant output, equation (10) can be used to estimate total annual packaging costs. For example, suppose that a plant with a capacity output rate of 5,000 pounds per hour is operating over a 500-hour season. During the season assume that 300 hours are spent packaging retail style and that 100 hours each are spent packaging institutional and bulk styles, respectively. With the conditions assumed, the symbols in equation (3) are:

(R) = 5,000 pounds of plant output capacity per hour.
(H_r) = 300 hours operated, retail packaging.
(H_i) = 100 hours operated, institutional packaging.
(H_b) = 100 hours operated, bulk packaging.

Total annual packaging costs can be computed by substituting these values in equation (10), that is:

$$\begin{aligned} TSC &= \$4{,}345 + \$856(5) + \$24.730(300)(5) + \$14.480(100)(5) + \$4.590(100)(5) \\ &= \$4{,}345 + \$4{,}280 + \$37{,}095 + \$7{,}240 + \$2{,}295 \\ &= \$55{,}255 \end{aligned}$$

Therefore, total season packaging cost for a plant operating under the above conditions is $55,255. The planning equation can be used in a similar manner to compute total annual packaging or filling costs with any given rate of plant output and hours of packaging each of the three styles.

Total annual packaging costs vary substantially with variations in the proportions packed in each of the three styles. The effect of variations in

proportions packed in each of the various styles on total annual packaging cost is illustrated in Figure 12 for plants with a 500-hour operating season. The figure shows the lower and upper range in total season costs as the proportions packed vary from 100 per cent bulk to 100 per cent retail.

Casing

The principal variations among casing methods involve the degree of mechanization associated with the case-fill and case-seal operations and the type of freezing operation. In California all plants observed used either the tray-tunnel or plate-freeze methods for freezing Lima beans.[1]

Four methods of carton casing--classified according to their degree of mechanization--were analyzed in relation to estimated quantities and costs of labor and equipment required at various capacity output rates and length of season. Crew requirements for each of these methods described below are summarized in Table 11. With Methods A and B the equipment requirements and layouts are equally adaptable for retail or institution carton casing. The machine case filling equipment used with Methods C and D is adapted for retail casing only, and additional facilities are required for manually filling cases of institutional cartons.

Method A--manual fill and seal--was the least mechanized method considered. With this method all job components are manually performed. These components include: (1) get full tray from freezer skid and set off to case-in table; (2) stencil, form, and stitch case; (3) fill case; (4) seal case; and (5) set off to pallet. The stenciling job involves obtaining bundles of flat cases from temporary storage, placing them on the stencil table for removal of twine bindings, stenciling each flat, and setting it aside for forming and stitching. The stenciled flats are formed and the bottoms stitched by a worker operating a wire case stitcher. The case-in job involves getting and placing the formed and stitched case on a skate-wheel conveyor, grasping six

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[1] For a description of the various methods used in the freezing operation, see Reed, Robert H., Survey of the Pacific Coast Frozen Fruit and Vegetable Industry (Berkeley: University of California, Division of Agricultural Sciences, Agricultural Experiment Station, 1957), 36p. (Giannini Foundation Mimeographed Report No. 198.) Processed.

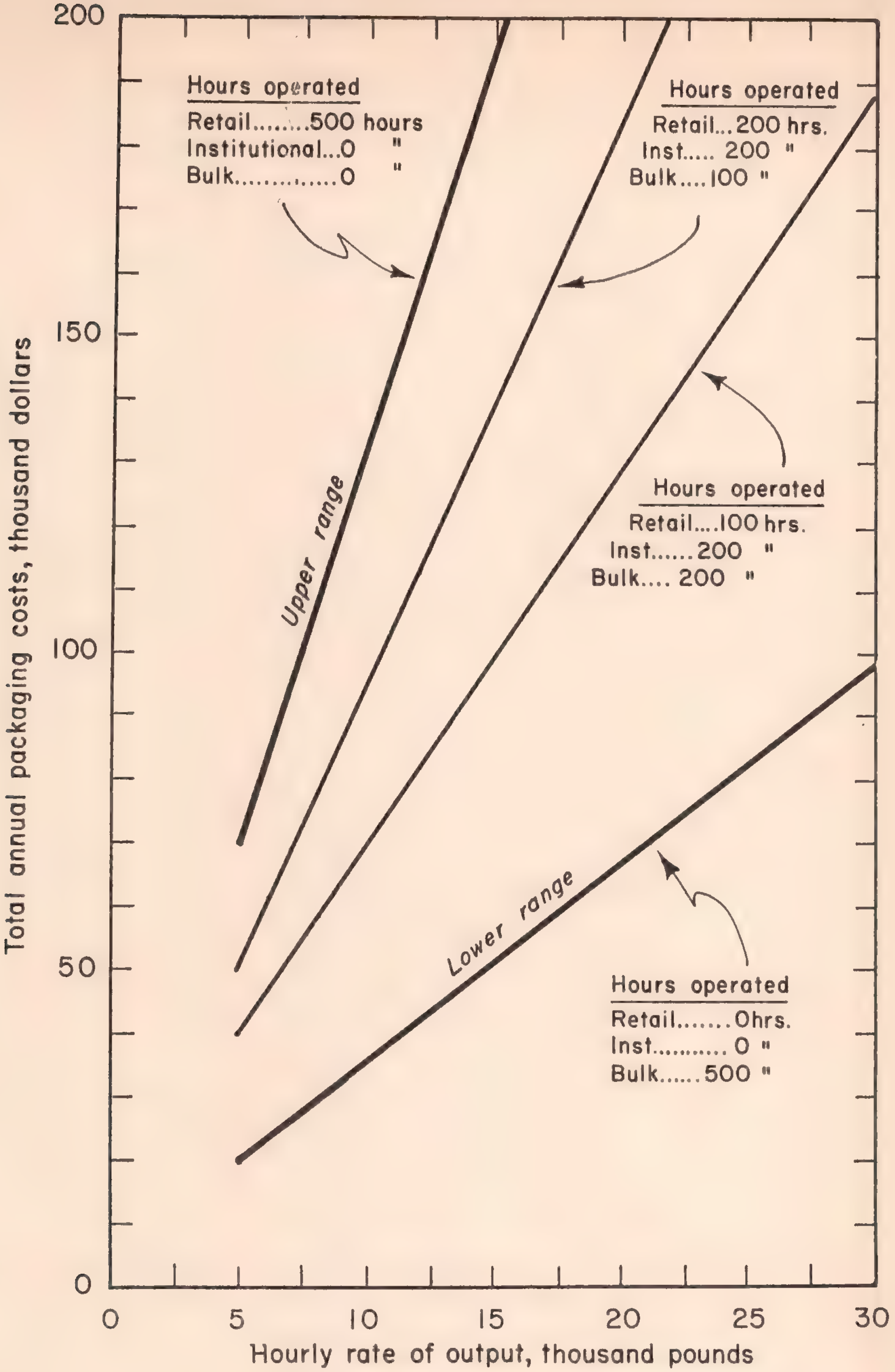

Figure 12. Total Annual Packaging Costs in Relation to Capacity Output Rates for Lima Bean Freezing Plants Packing Different Proportions of Retail, Institutional, and Bulk Styles for a 500-Hour Operating Season, California, 1958.

TABLE 11

Crew Requirements for Casing-In Tray Frozen Lima Beans,
by Methods Used, Rate of Output, and Style of Pack
California, 1958

Rate of output[a] pounds per hour	Retail style[b]								Institutional style[c]						
	Form case	Stitch case	Stencil case	Dump trays	Fill case	Guide cartons	Manual seal and/or setoff	Total	Form case	Stitch case	Stencil case	Dump trays	Fill case	Manual seal and/or setoff	Total
	number of workers														
	Method A														
5,000	1	1	1	1	2	d/	1	7	1	1	--[e]	1	1	1	5
10,000	2	2	1	2	4		3	14	1	2	--	2	2	2	9
15,000	2	3	2	3	5		4	19	1	2	1	2	3	2	11
20,000	3	4	2	4	7		5	25	2	2	1	3	4	3	14
25,000	3	5	3	5	8		6	30	2	3	2	3	5	3	17
30,000	4	6	3	6	10		7	36	3	3	2	4	6	4	22
	Method B														
5,000	1		1	1	2		1	6	1		--	1	1	1	4
10,000	2		1	2	4		2	11	1		--	2	2	1	6
15,000	2		2	3	5		3	15	1		1	2	3	2	9
20,000	3		2	4	7		3	19	2		1	3	4	2	12
25,000	3		3	5	8		4	23	2		2	3	5	3	15
30,000	4		3	6	10		5	29	3		2	4	6	3	18
	Method C														
5,000	1		1	1	1	1	1	6	1		--	1	1	1	4
10,000	2		1	2	2	2	2	11	1		--	2	2	1	6
15,000	2		2	3	2	2	3	14	1		1	2	3	2	9
20,000	3		2	4	3	3	3	18	2		1	3	4	2	12
25,000	3		3	5	3	3	4	21	2		2	3	5	3	15
30,000	4		3	6	4	4	5	26	3		2	4	6	3	18
	Method D														
5,000	1	1	1	1	1	1	1	7	1	1	--	1	1	1	5
10,000	2	2	1	2	2	2	2	14	1	2	--	2	2	2	9
15,000	2	3	2	3	2	2	3	18	1	2	1	2	3	2	11
20,000	3	4	2	4	3	3	3	24	2	2	1	3	4	3	14
25,000	3	5	3	5	3	3	4	28	2	3	2	3	5	3	17
30,000	4	6	3	6	4	4	5	34	3	3	2	4	6	4	22

a/ To convert pounds to 24/10-ounce cases, divide by 15.
To convert pounds to 12/2½-pound cases, divide by 30.

b/ Retail carton casing (10-ounce cartons, 24 per case):

Production standards (cases per hour): Form case (Methods A, B, C, and D)--549; stitch case (Methods A and D)--334; stencil case (Methods A, B, C, and D)--790; dump trays (Methods A, B, C, and D)--334; manual fill (Methods A and B)--213; machine fill (Methods C and D)--576; manual seal and setoff (Methods A and D)--300; machine seal and setoff (Methods B and C)--467; and guide cartons (Methods C and D)--576.

Wage rates: Dump trays, manual seal and setoff, and machine seal and setoff--$1.86 per hour; and all other jobs--$1.69 per hour.

c/ Institutional carton casing (2½-pound cartons, 12 per case):

Production standards (cases per hour): Form case (Methods A, B, C, and D)--494; stitch case (Methods A and D)--334; stencil case (Methods A, B, C, and D)--700; dump trays (Methods A, B, C, and D)--285; manual fill (Methods A, B, C, and D)--200; manual seal and setoff (Methods A and D)--290; and machine seal and setoff (Methods B and C)--450.

Wage rates: Dump trays, manual seal and setoff, and machine seal and setoff--$1.86 per hour; and all other jobs--$1.69 per hour.

d/ Blanks indicate that this job is not required with this method.

e/ Dashes indicate that with low output rate this job is performed by the case-forming or stitching crew.

retail or four institutional cartons at a time and placing them in the case. As the case is filled, it is pushed along the case-in conveyor to the case sealing operation, where a worker applies glue to the flaps, usually with a 3-inch or 4-inch brush. The sealed case is then set off to a pallet for removal to cold storage.

In Method B—manual fill, machine seal—the labor involved in stitching the bottom and gluing the flaps is reduced by the addition of a top and bottom mechanical sealer and compressor unit. Other labor and equipment requirements are the same as in Method A.

With Method C the labor required to fill the case with retail cartons is reduced by the installation of a mechanical caser. In the retail casing operation, a worker gets a full tray of retail cartons from the freezer skid and dumps them to a 8' x 30" portable dump conveyor. As the cartons move over the ends of the dump conveyor, a worker arranges them in single file on the carton-intake conveyor leading to the mechanical caser. The caser operator forms the case and places it over a sleeve-type feeder where the cartons are filled in tier fashion by a pneumatically driven ram lever. When filled, the case is automatically released to a conveyor leading through a mechanical sealer and compressor and manually palletized for removal to storage. The portable tray-dump conveyor can be used as a case-in table for manually filling cases of institutional cartons. To use this equipment for filling cases of institutional cartons, rather than retail, the portable dump conveyor is moved so as to tie in with the lead-in conveyor of the mechanical sealer. Workers stationed at the end of the dump conveyor manually fill the case with institutional cartons. As the case is filled, it is conveyed through the mechanical sealer and compressor, then palletized manually.

Method D combines the techniques of Methods A and C. Case-in operations for both retail and institutional styles are identical to Method C, but the sealing is done manually as in Method A. The crew requirements for the retail casing operation are slightly less than with Method A but are greater than with Methods B and C. The crew requirements for the institutional casing operations are identical to those of Method A.

Crew requirements and estimated equipment requirements are shown in Tables 11 and 12, respectively. These data are the basis for estimated costs of labor and other variable inputs as well as the investment cost and annual fixed charge for equipment that are given in Table 13 for selected capacity rates of casing.

TABLE 12

Equipment Requirements for Casing Tray Frozen Lima Beans by Methods Used and Rate of Output,[a] California, 1958

Rate of output[b]	Case-in table[c]	Case-in machine[d]	Full case conveyor[e]	Sealer-compressor[f]		Case stitcher[g]	Stencil equipment[h]	Glue stand[i]	Set-off conveyor[j]	Tally desk[k]
pounds per hour	feet	number	feet	number	type	number			feet	number
Method A--Manual fill and seal										
5,000	8	1/	18[1]			1	1	1		1
10,000	16		26			2	1	1		1
15,000	20		30			3	2	2		1
20,000	28		48			4	2	2		1
25,000	32		52			5	3	2		1
30,000	40		60			6	3	2		1
Method B--Manual fill, machine seal										
5,000	8		16[2]	1	C		1		10	1
10,000	16		24	1	B		1		10	1
15,000	20		28	1	A		2		10	1
20,000	28		46	2	B		2		20	1
25,000	32		48	1 1	A B		3		20	1
30,000	40		56	2	A		3		20	1
Method C--Machine fill and seal										
5,000		1	7[3]	1	C		1		10	1
10,000		2	24	1	B		1		10	1
15,000		2	24	1	A		2		10	1
20,000		3	31	2	B		2		20	1
25,000		3	31	1 1	A B		3		20	1
30,000		4	48	2	A		3		20	1
Method D--Machine fill, manual seal										
5,000		1	10[4]			1	1	1		1
10,000		2	20			2	1	1		1
15,000		2	20			3	2	2		1
20,000		3	30			4	2	2		1
25,000		3	30			5	3	2		1
30,000		4	40			6	3	2		1

a/ Equipment requirements for both retail and institutional casing.

b/ To convert pounds to 24/10-ounce cases, divide by 15; to convert pounds to 12/2½-pound cases, divide by 30.

c/ Wood construction 30 inches set-on surface for trays; 30 inches case-in surface inclined 25 degrees, 4 feet allowed for work place, plant or custom made--$75 per 4-foot section, installed.

d/ Pneumatic ram-lever type, 1/4-horsepower motor for retail cartons only. Capacity, 576 24/10-ounce cases per hour with 15 per cent allowance for wait and unavoidable delay. Includes tray dump conveyor assembly, 8' x 30" with 1/4-horsepower motor and drive; modified for use as case-in conveyor for institutional carton casing. Machine caser--$2,495, installed; tray dump conveyor--$719, installed.

e/ To convey full cases to sealer-compressor unit or to manual seal and set-off station.

1. Skate-wheel conveyor, 12 inches wide by specified lengths.
2. Includes: (1) skate-wheel conveyor, 12 inches by length of case-in table--$5 per foot, installed; and (2) an 8' x 12" belt conveyor with ½-horsepower motor for distributing cases to sealer, $247 + $10.30 per foot of conveyor, installed.
3. Belt conveyor, 12 inches by specified lengths. Includes: motor and drives with box turn and/or converger units. Installed costs are estimated as $247 + $10.30 per foot of conveyor plus $480 for each box turn or converger. Conveyors modified for use when casing institutional cartons.
4. Skate wheel type--$5 per foot, installed.

f/ Top and bottom sealer and compressor unit, adjustable for different case dimensions.

g/ Type A: 28-foot compressor, capacity, approximately 1,170 24/10-ounce cases or 17,500 pounds per hour--$6,460, installed.

Type B: 20-foot compressor, capacity, approximately 810 24/10-ounce cases or 12,150 pounds per hour--$5,832, installed.

Type C: 12-foot compressor, capacity, approximately 476 24/10-ounce cases or 7,140 pounds per hour--$4,998, installed.

g/ Standard type, 12-inch throat, capacity, 260 stitches per minute--$675.

h/ Includes stencil table, wheel, and pad. One set required for each 790 cases per hour--$60.

i/ Trough type, situated over set-off conveyor.

j/ Skate wheel, 10' x 12"--$5 per foot.

k/ Desk surface, 22" x 60" x 1", single drawer--$30.

l/ Blanks indicate equipment is not used with methods indicated.

TABLE 13

Equipment Replacement Costs, Annual Fixed Charges, and Variable Costs for Casing Tray Frozen Lima Beans by Methods Used and Rate of Output
California, 1958

Rate of output	Fixed costs, retail and institutional a/						Variable costs, retail				Variable costs, institutional			
	Replacement costs b/			Annual fixed charges c/										
	Equipment	Belting	Total	Equipment c/	Belting d/	Total	Labor e/	Miscellaneous, power and repairs f/	Cases g/	Total	Labor e/	Miscellaneous, power and repairs f/	Cases h/	Total
pounds per hour	dollars													
	Method A													
5,000	1,030	i/	1,030	170		170	12.14	1.09	30.15	43.38	8.79	0.59	17.98	27.36
10,000	1,895		1,895	313		313	24.45	2.13	60.30	86.88	15.89	1.14	35.85	52.88
15,000	2,750		2,750	454		454	33.21	3.18	90.45	126.84	19.27	1.69	53.82	74.78
20,000	3,665		3,665	605		605	43.56	4.27	120.60	168.43	24.51	2.28	71.69	98.48
25,000	4,495		4,495	742		742	52.43	5.31	150.75	208.49	29.58	2.82	89.67	122.07
30,000	5,360		5,360	884		884	62.88	6.36	180.90	250.14	38.54	3.38	107.54	149.46
	Method B													
5,000	5,507	39	5,546	908	10	918	10.45	1.07	30.15	41.67	7.10	0.47	17.98	25.55
10,000	6,381	39	6,420	1,053	10	1,063	19.22	1.86	60.30	81.38	10.65	0.88	35.85	47.38
15,000	7,089	39	7,128	1,170	10	1,180	26.30	2.65	90.45	119.40	15.89	1.31	53.82	71.02
20,000	12,712	79	12,791	2,097	20	2,117	33.21	3.73	120.60	157.54	21.13	1.78	71.69	94.60
25,000	13,420	79	13,499	2,214	20	2,234	40.29	4.51	150.75	195.55	26.37	2.20	89.67	118.24
30,000	14,088	79	14,167	2,338	20	2,358	49.06	5.30	180.90	235.26	31.61	2.62	107.54	141.77
	Method C													
5,000	8,471	120	8,591	1,398	30	1,428	10.45	1.19	30.15	41.79	7.10	0.47	17.98	25.55
10,000	13,207	290	13,497	2,179	73	2,252	19.22	2.20	60.30	81.72	10.65	0.88	35.85	47.38
15,000	13,895	290	14,185	2,293	73	2,366	24.61	3.00	90.45	118.06	15.89	1.31	53.82	71.02
20,000	22,482	411	22,893	3,710	103	3,813	31.53	4.19	120.60	156.32	21.13	1.78	71.69	94.60
25,000	23,170	411	23,581	3,823	103	3,926	36.92	4.99	150.75	192.66	26.37	2.20	89.67	118.24
30,000	27,700	580	28,280	4,571	145	4,716	45.69	5.99	180.90	232.58	31.61	2.62	107.54	141.77
	Method D													
5,000	3,854	86	3,940	636	22	658	12.14	1.26	30.15	43.55	8.79	0.59	17.98	27.36
10,000	7,593	172	7,765	1,253	43	1,296	24.45	2.50	60.30	87.25	15.89	1.14	35.85	52.88
15,000	8,353	172	8,525	1,378	43	1,421	31.53	3.57	90.45	125.55	19.27	1.69	53.82	74.78
20,000	12,092	258	12,350	1,995	65	2,060	41.98	4.80	120.60	167.38	24.51	2.28	71.69	98.48
25,000	12,827	258	13,085	2,116	65	2,181	49.06	5.88	150.75	205.69	29.58	2.82	89.67	122.07
30,000	16,566	344	16,910	2,733	86	2,819	59.51	7.10	180.90	247.51	38.54	3.38	107.54	149.46

a/ Identical equipment is used for casing both retail and institutional styles.

b/ Replacement costs derived from applying unit equipment costs to equipment requirements.

c/ Estimated as 16.5 per cent of equipment replacement costs. Includes depreciation--10 per cent; taxes--1 per cent; insurance--1 per cent; interest on investment--3 per cent (approximately 5.5 per cent of undepreciated balance); and fixed repairs maintenance--1.5 per cent.

d/ Estimated as 25 per cent of belting replacement cost. Includes depreciation--20 per cent; taxes--1 per cent; insurance--1 per cent; and interest on investment--3 per cent.

e/ Calculated from crew requirements and wage rates given in Table 11.

f/ Power: Estimated as 2.5 cents per horsepower hour. Variable repairs: Estimated as 0.5 per cent of replacement cost per 100 hours operation. Miscellaneous: Includes glue estimated as $75 per 100 gallons and wire at $28 per 100 pounds.

g/ Costs based on 24/10-ounce cases, 4 panels, 2 colors, estimated at $90 per 1,000 cases.

h/ Costs based on 12/2-1/2 pound cases, 4 panels, 2 colors, estimated at $107 per 1,000 cases.

i/ Blanks indicate that annual fixed charges of belting does not apply in Method A.

Total annual casing costs, related to casing method, style of pack, hourly rates of output, and length of operating season were calculated from the data given in Table 13. Figure 13 shows these cost relationships for Methods A, B, C, and D for three different lengths of season. Method B is shown to be the least-cost method for both retail and institutional styles over all ranges of output rates considered. Consequently, the equipment, labor, and cost estimates for Method B were used in developing a planning equation for estimating casing costs in plants packing various proportions of their total pack in retail and institutional styles.

Annual Fixed Costs

The annual fixed charges shown in Table 13 for Method B operations were used to develop the generalized expression showing how these costs vary with the size of plant—measured in capacity output-rates—as given in equation (11) below:

$$(11) \quad TFC = \$480 + \$67(R)$$

where

TFC is the total annual fixed cost of casing Lima beans, and
(R) is 1,000 pounds of plant capacity output per hour.

Annual Variable Casing Costs

As with packaging or filling operations, estimation of annual variable costs for the casing stage is complicated because they are not related to the output of a uniquely defined "product" or style of container. Estimation of annual variable casing costs may be simplified, however, by determining the relationship between hourly variable costs of casing each of the two styles and hourly volumes of output. The procedure involves plotting the variable cost points given in Table 13 against hourly rates of output for each of the two styles and measuring the "fit" of a line smoothed through the points as illustrated in Figure 14. The figure shows the relation of hourly variable cost to hourly volume is approximately linear and through the origin for both container styles. This means that unit cost per pound—for casing each style of pack—is constant at all capacity rates of casing and is independent of the scale of operations. Average unit costs based on the points in Figure 14 are $7.952 and $4.712 per 1,000 pounds cased in retail and institutional styles,

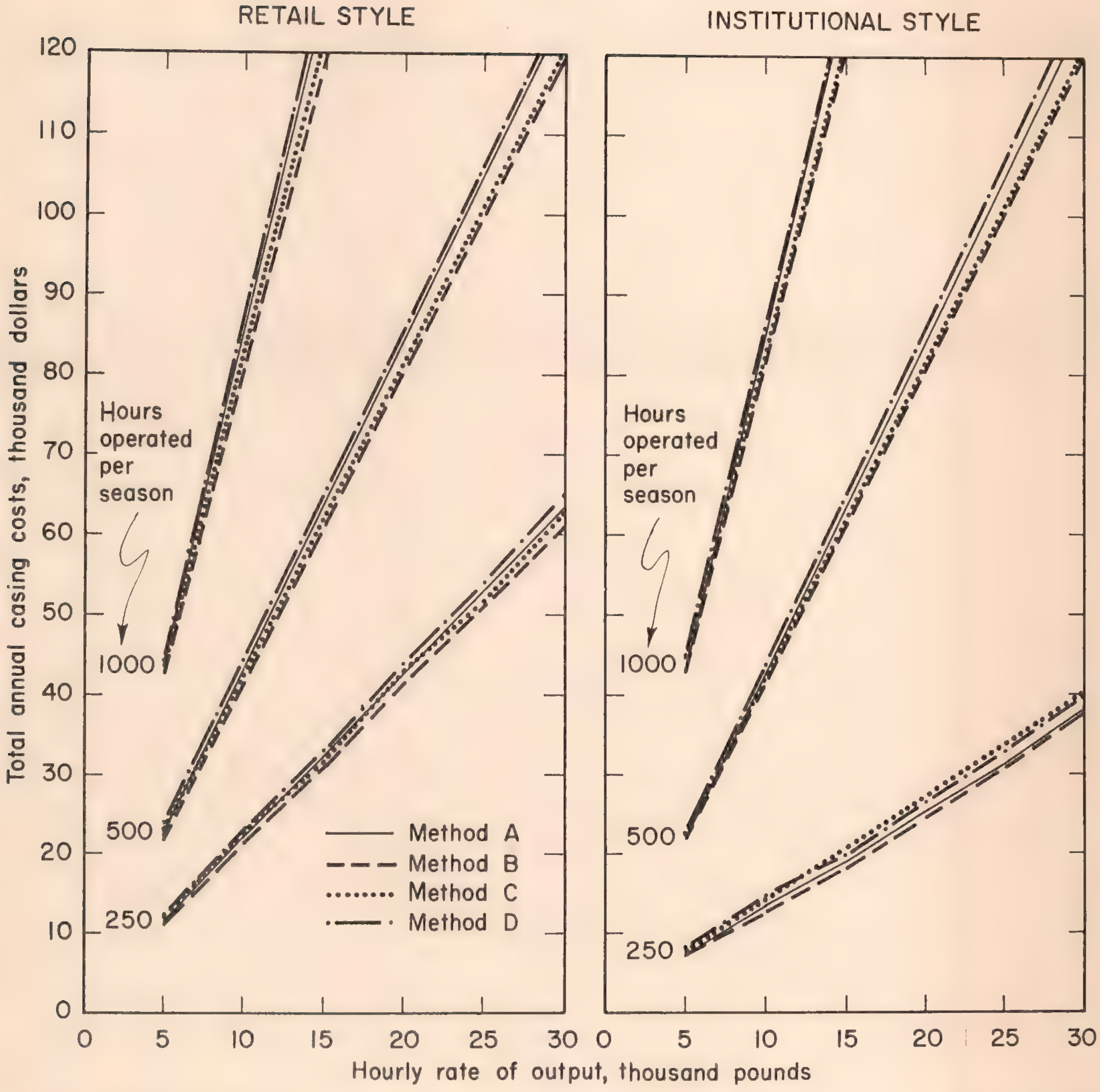

Figure 13. Total Annual Costs of Casing Tray Frozen Lima Beans by Methods Used, Rate of Output, Length of Season, and Style of Pack, California, 1958.

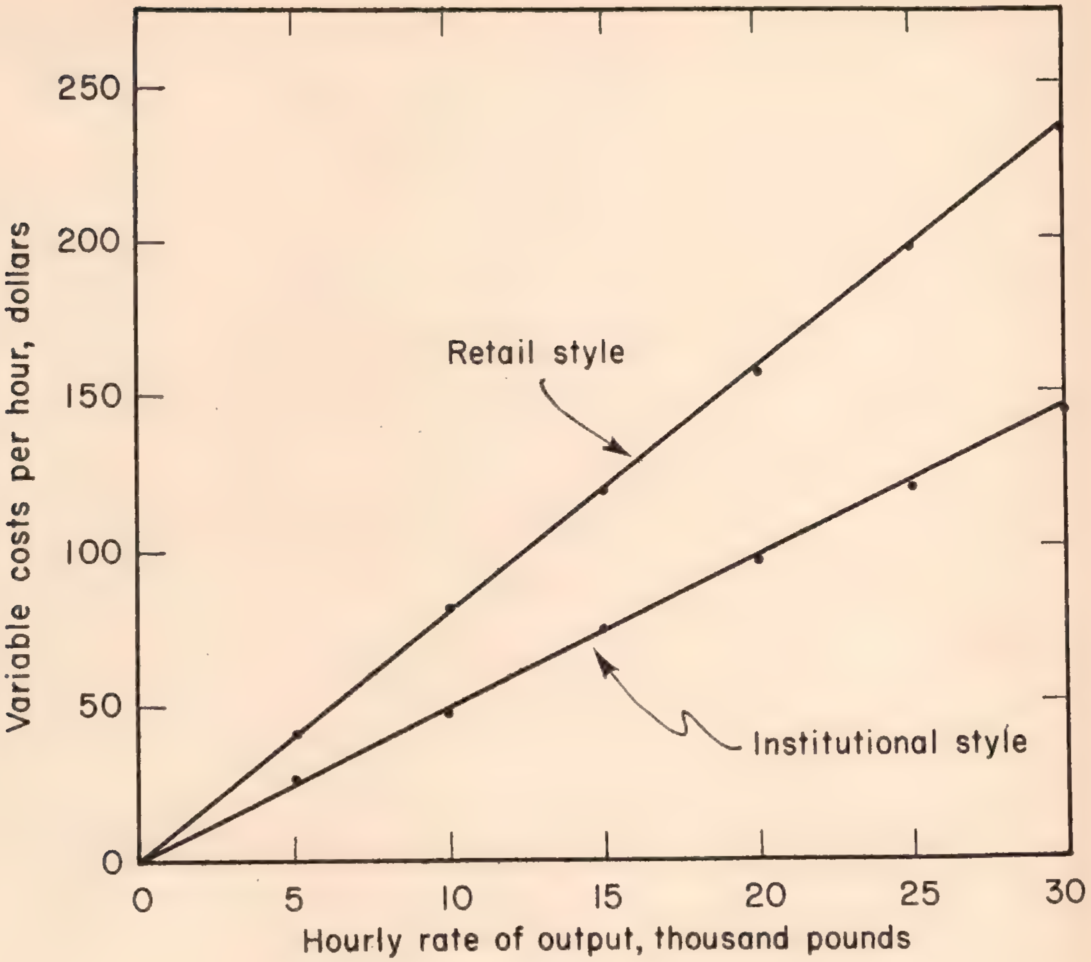

Figure 14. Relation of Hourly Variable Casing Costs to Hourly Rates of Output in Lima Bean Freezing Plants Equipped to Case Retail and Institutional Cartons, California, 1958.

respectively. Total variable casing costs per season can be estimated by applying the unit costs given above to the total season volume packed in each style. Annual variable casing costs, calculated on this basis, are given in equation (12) below for plants equipped with the least-cost casing method (Method B).

$$\text{(12)} \quad TVC = \$7.952(H_r)(R) + \$4.712(H_i)(R)$$

where

TVC is total variable costs of casing per season.
H_r is number of hours operated, retail style.
H_i is number of hours operated, institutional style.
R is 1,000 pounds cased per hour.

This equation can be used to estimate annual variable casing costs for any proportion of total season volume that is packed in retail or institutional styles.

Total Annual Casing Costs

Total annual casing costs for any given plant capacity and length of operating season are the sum of the corresponding annual fixed and variable cost components. The generalized total season or planning cost equation for plants casing any combination of retail and institutional cartons is obtained by combining equations (11) and (12) above and is given in the expression below.

$$\text{(13)} \quad TSC = \$480 + \$67(R) + \$7.952(H_r)(R) + \$4.712(H_i)(R)$$

where

TSC is the total annual cost of casing Lima beans and (R), (H_r), and (H_i) are as defined in equation (12) above.

For any given length of season, proportions packed in the various styles, and capacity rate of output, equation (13) can be used to estimate total annual casing costs. Total annual casing costs for plants casing different proportions of retail and institutional styles are shown in Figure 15 for a 500-hour operating season.

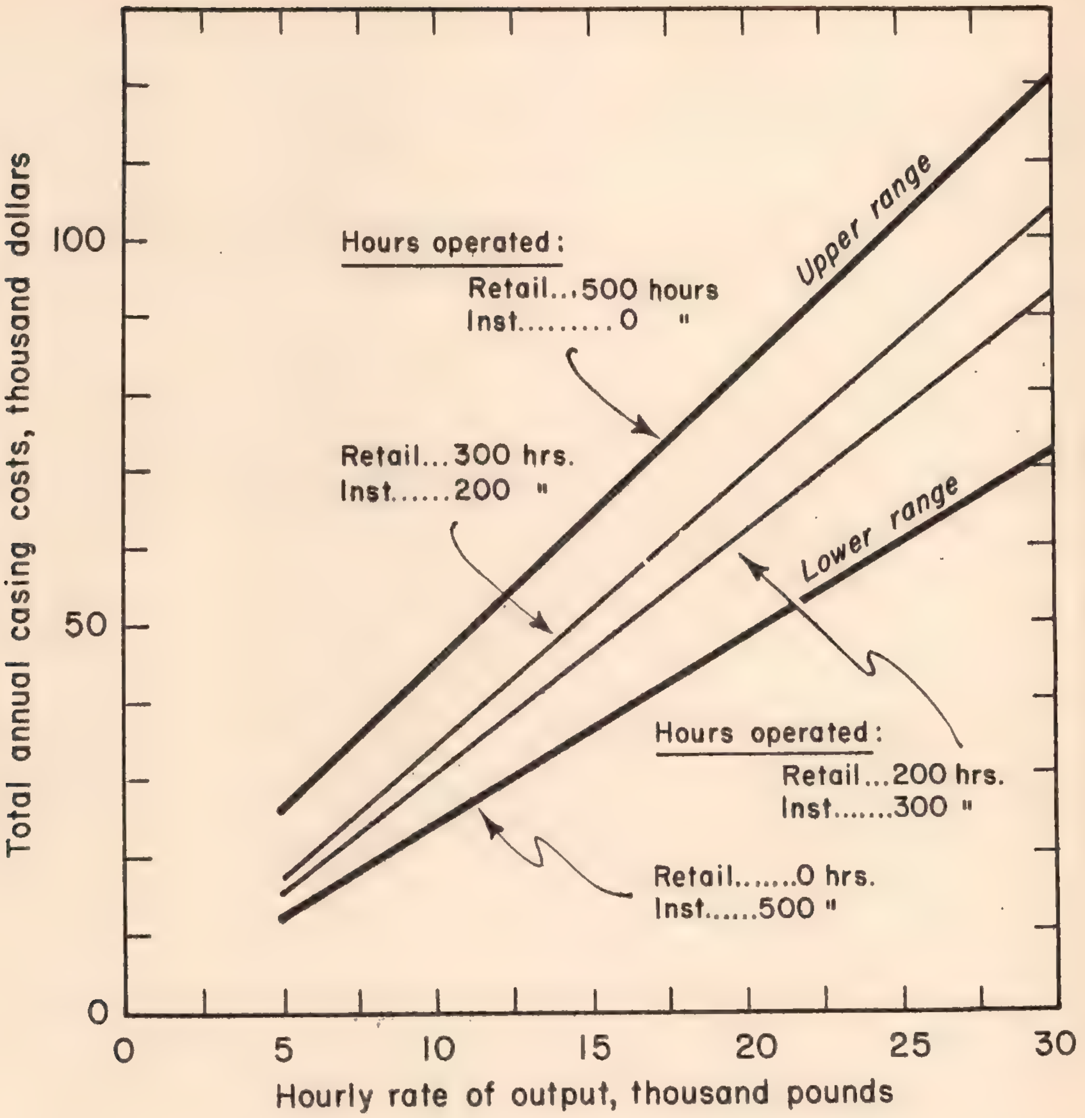

Figure 15. Total Annual Casing Costs in Relation to Capacity Output Rates for Lima Bean Freezing Plants Packing Different Proportions of Retail and Institutional Styles for a 500-Hour Operating Season, California, 1958.

Variable Water Inputs and Costs

Variable water inputs and costs are, for the most part, associated with particular stages of plant operation. For convenience, however, the requirements and variable costs of water for the plant as a whole are summarized in this section. Estimated rates of water usage with the types and amounts of equipment previously developed for each stage are given for selected plant output capacity rates in Table 14. These estimates are based on data obtained from equipment manufacturers, processors, contractors, and on studies of equipment operating characteristics.

Estimated water costs--also given in Table 14--are obtained by applying average public utility for industrial water usage.[1] Typical rates involve a fixed annual stand-by charge and a unit price of 13 cents per 100 cubic feet of water used. The cost data in Table 14 are the basis for estimated total water costs shown graphically for selected lengths of season in Figure 16 as well as for the planning equation below:

$$(14) \qquad TVC_w = \$166 + \$15.01(R) + \$0.1872(H) + \$0.5380(R)(H)$$

where

TVC_w is total variable water costs per season.
R is 1,000 pounds of hourly plant capacity.
H is hours of plant operation per season.

Freezing and First Month's Storage

As Lima beans are processed during a relatively short season, cold-storage requirements beyond the first month depend primarily upon the initial volume entering storage and the rate of sales. As costs associated with storage beyond the first month can be logically classified as selling expenses, they are not considered in this report.

Freezing and first month's storage costs, however, enter directly as an operating expense. These costs are related to the type of product packed,

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[1] The development of pumping costs for privately owned wells was not attempted as the depth to static ground water levels varies widely within and among processing areas.

TABLE 14

Hourly Water Inputs and Variable and Stand-By Costs in Relation to Selected Capacity Output Rates in Lima Bean Freezing Plants, California, 1958

	Hourly water inputs[a]					
Rate of output	Receiving and initial cleaning	Blanching and second quality grade	Pick-belt and filler distribution	Total	Hourly variable costs[b]	Annual stand-by charge[c]
pounds per hour	thousand gallons				dollars	
5,000	5.3	5.5	5.0	15.8	2.74	180
10,000	15.5	7.9	8.3	31.7	5.50	300
15,000	18.8	15.2	13.9	47.9	8.31	400
20,000	28.1	19.4	17.2	64.7	11.22	400
25,000	35.0	25.1	21.7	81.8	14.18	600
30,000	39.6	29.0	25.1	93.7	16.24	600

a/ For equipment items, see specific stage analyses.

b/ Based on average PUC rates--approximately 13 cents per 100 cubic feet (750 gallons).

c/ Stand-by charge for meter service, etc.

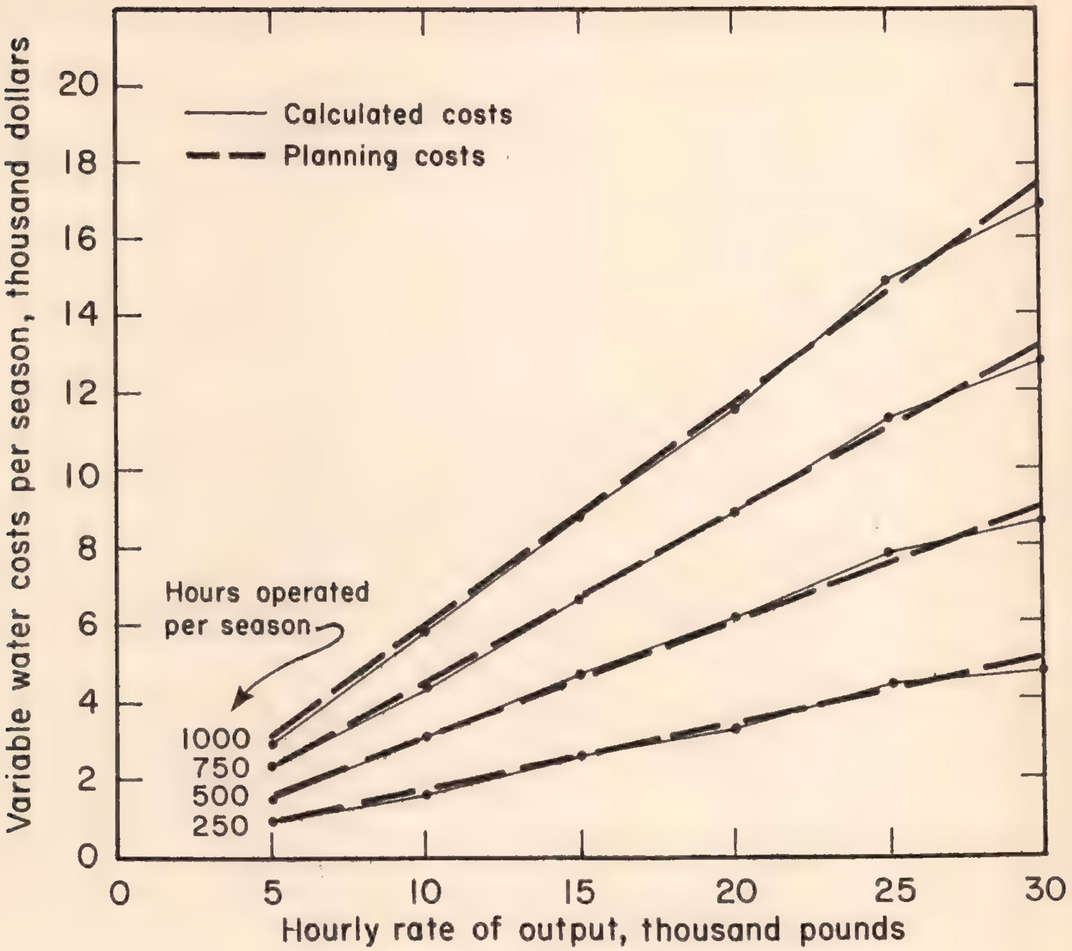

Figure 16. Total Variable Water Costs in Relation to Length of Season and Rate of Plant Output in Processing Lima Beans for Freezing, California, 1958.

style of container, storage or handling methods used, and length of freezing season and storage. Development of precise relationships among these variables requires a detailed engineering-economic analysis of freezing and storage operations. Such results are not available, and the costs used in this analysis are based on data obtained from plant records. Accordingly, total freezing and first month's storage costs are estimated on the basis of annual volume and a unit freezing and storage cost, representative of rates paid for custom service by plants studied. Costs estimated on this basis are summarized in the expression below and are graphically depicted in Figure 17.

$$(15) \quad TSC = \$8.30(R)(H)$$

where

TSC is the total annual cost of freezing and first month's storage.
R is 1,000 pounds of plant output per hour.
H is hours operated per season.

As about 75 per cent of the plants observed rely on commercial cold storage companies for freezing and storage operation, the costs summarized in equation (15) are considered representative of the costs experienced by the majority of California plants.

In-Plant Transportation of Cased Goods and Packaging Materials

Fork-lift trucks are used in Lima bean processing for transferring cased goods to cold storage and for supplying packaging and miscellaneous materials. As all these activities are often performed by the same equipment and crew, they are combined in this report to form one operating stage.

Net time requirements for the various components of the lift-truck jobs observed were measured by time and production studies in a number of freezing plants and fresh fruit packing houses.1/ Total net time per round trip is

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1/ For a more detailed analysis refer to Sammet, In-Plant Transportation Costs as Related to Materials Handling Methods--Apple and Pear Packing. (Berkeley: University of California, College of Agriculture, Agricultural Experiment Station, January, 1953), 57p. (Giannini Foundation Mimeographed Report No. 142.) Processed. (The sixth report in a series on Efficiency in Fruit Marketing.)

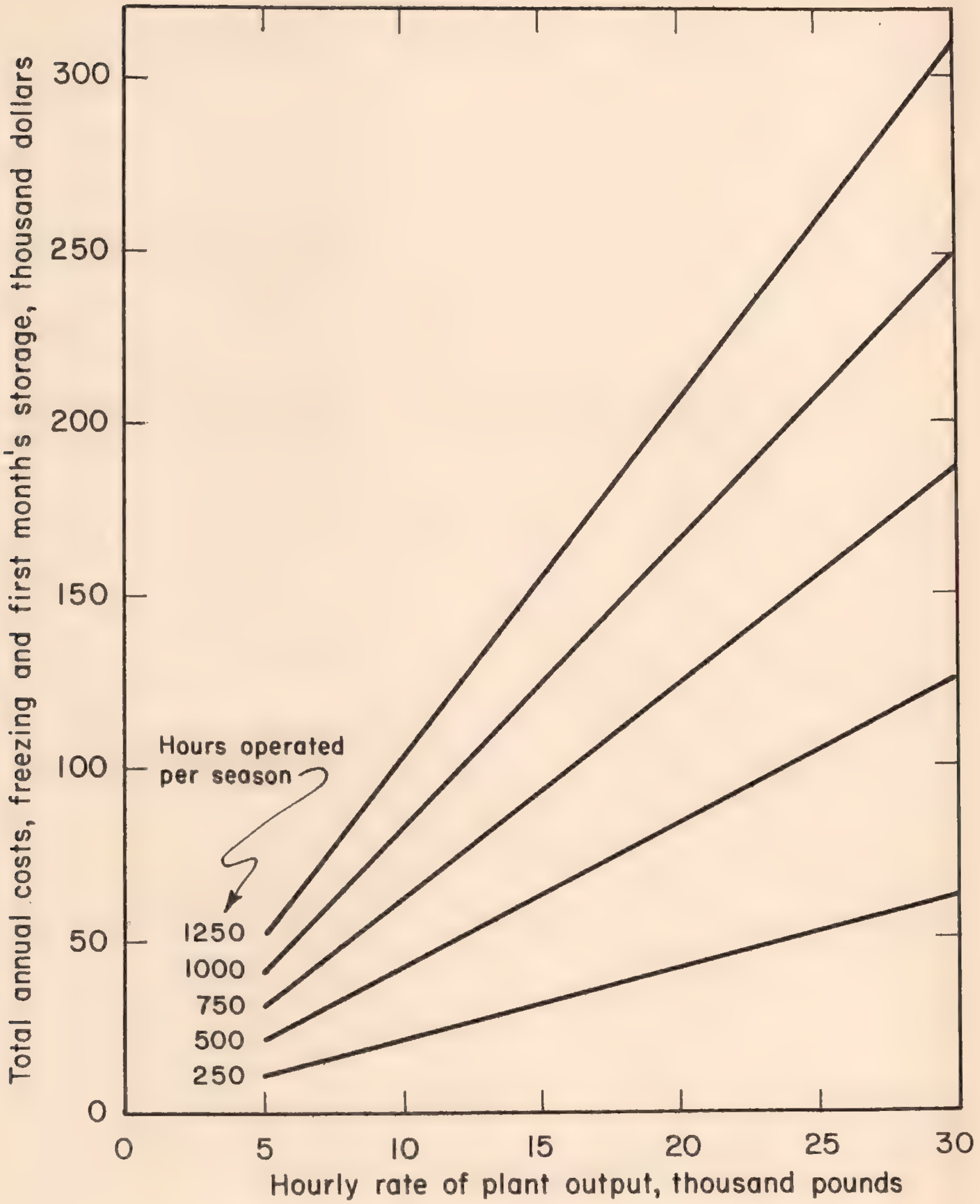

Figure 17. Total Annual Costs of Freezing and First Month's Storage of Lima Beans in Relation to Rate of Plant Output and Length of Operating Season, California, 1958.

comprised of two components--"turn around" and transit time. "Turn around" activities involve operations that are common for each trip such as engaging the load and set off. Transit time is the time required to move loaded pallets to delivery point and return, unloaded, to the pick-up point. Net time requirements on this basis are summarized in the following relation: Net time per round trip = 1.308 + 0.005(D), where "D" represents round-trip distance in feet. This expression states that 1.308 minutes are required per trip for "turn around" activities plus 0.005 minutes per foot traveled between the pick-up and delivery point and return.

The average round-trip distance from the casing area to the warehouse was 300 feet in the plants studied. As pallets were normally loaded with 90 retail or 45 institutional cases each, the weight per pallet load is approximately 1,350 pounds.[1] Time requirements for supplying packaging and miscellaneous materials were estimated as amounting to 10 per cent of the total trucking time.

With these specifications regarding distance traveled and weight per pallet load, lift-truck requirements per 1,000 pounds of plant pack-out are as follows.[2]

Job	Minutes required
Transport full cases to cold storage	2.080
Transport packaging and miscellaneous materials	0.231
Unavoidable delay[3]	0.578
Total time per 1,000 pounds pack-out	2.889

The total time requirement per 1,000 pounds pack-out given above can be used to estimate the number of fork trucks and operators required for any

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[1] Retail cases considered in this report contain 24 10-ounce cartons. Institutional cases considered contain 12 2-1/2-pound cartons.

[2] Net time requirements per 1,000 pounds are obtained as follows: 1,000/1,350 (1.308 + 0.005D). With D specified as 300 feet, net time requirements for transport of full cases is 1,000/1,350 (2.2808) = 2.080 minutes per 1,000 pounds as given in the above table.

[3] Includes scheduled rest periods and nonproductive time due to contingencies, personal time, etc. Various studies indicate that this varies in particular plants from 15 to 40 per cent of the total time input. Twenty per cent is used here as a practical minimum.

given plant output rate. On this basis, one fork-lift truck and driver will be required for every 20,700 pounds of plant pack-out.

Although a large part of the work performed in transporting packaging and miscellaneous materials may be accomplished between shifts or during other periods of plant inactivity, this portion of the transportation load represents only a small percentage of the time required in the over-all transportation operation. General observations of plant equipment inventories suggest that the procedure used gives good estimates of fork-truck requirements during peak-load periods.

The hourly variable costs of operating a fork-lift truck comprise a charge of 29 cents for variable repairs and maintenance, 21 cents for fuel, and \$2.10 for the operator.

The cost rates and standards presented above are used to estimate the crew and equipment requirements and costs given in Table 15. Total annual costs based on the entries in the table are illustrated in Figure 18. "Planning" costs, represented by the heavy dashed lines in Figure 18, are given by the following expression:

$$(16)\quad TSC = \$425 + \$48(R) + \$1.0800(H) + \$0.1300(R)(H)$$

where

TSC is total season cost in dollars of the in-plant transportation of cased goods and packaging materials.
R is 1,000 pounds of plant output per hour.
H is hours operated per season.

Investment Cost of Plant Building, Water Piping, and Electrical Wiring

Plant Buildings[1]

The costs of plant buildings used in this study are based on engineering estimates of replacement costs for plants of concrete sidewall construction

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[1] Material on the section of building costs is drawn from Sammet, "Economic and Engineering Factors . . .," and from Sammet and I. F. Davis, Building and Equipment Costs, Apple and Pear Packing (Berkeley: University of California, College of Agriculture, Agricultural Experiment Station, December, 1952.) 38p. (Giannini Foundation Mimeographed Report No. 141.) Processed. (The fifth report in a series on Efficiency in Fruit Marketing.)

TABLE 15

Equipment Replacement Costs, Annual Fixed Charges, and Hourly Variable Costs of Fork Lift Truck Transportation in Relation to Capacity Pack-Out Rates, Lima Bean Freezing Plants, California, 1958

Rate of plant output	Variable costs			Equipment	
	Lift truck driver	Repairs and fuel[a]	Total	Replacement cost[b]	Annual fixed charge[c]
pounds per hour	dollars				
5,000	2.10	.12	2.22	5,775	953
10,000	2.10	.24	2.34	5,775	953
15,000	2.10	.36	2.46	5,775	953
20,000	2.10	.48	2.58	5,775	953
25,000	4.20	.60	4.80	11,550	1,906
30,000	4.20	.75	4.95	11,550	1,906

a/ Variable repairs estimated as 0.5 per cent of replacement cost per 100 hours operation.

b/ Lift truck, standard type, 4,000 pounds capacity, gas driven--$5,775, delivered.

c/ Estimated as percentage of replacement cost. Includes depreciation--10 per cent; taxes--1 per cent; insurance--1 per cent; interest--3 per cent; fixed repairs and overhaul--1.5 per cent; for a total of 16.5 per cent

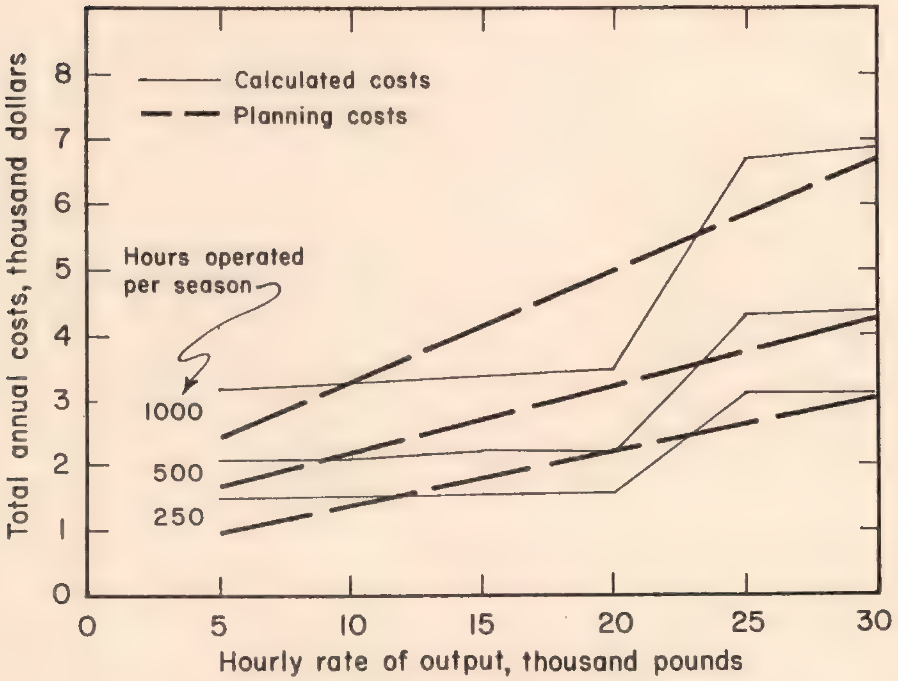

Figure 18. Total Annual Costs of In-Plant Transportation of Cased Goods and Packaging Materials in Lima Bean Freezing Plants in Relation to Rate of Plant Output and Length of Operating Season, California, 1958.

with a clear height to the roof trusses of 18 feet. In general, the estimating procedure involves two major steps: (1) determination of floor space requirements for a series of efficiently organized plants of different capacity output rates and (2) estimation of construction costs for each building in the series by applying current prices to the quantities of labor and materials required for each structure.

Floor space requirements for well-organized plants of various capacities were developed from an analysis of floor plans of plants cooperating in the study. Space for processing, temporary raw product storage, packing materials storage, boiler room, repair shop, rest rooms, and offices is included, while space for freezing and cold-storage facilities is not. Space requirements in terms of total roofed area for plants of three different capacities are given in Table 16. These estimates are the basis for a general expression of space required in relation to plant capacity as follows: $A = 5{,}000 + 1{,}005(R)$. In this expression the symbol A represents the total roofed area of the building, excluding freezing and cold storage facilities, while R represents 1,000 pounds of plant-output capacity per hour.

Estimated construction costs for the type of building construction considered in this report are given in Table 16 plants of three different sizes. These costs are the basis for a generalized expression showing total building investment replacement costs in relation to plant size as measured by capacity output rates. This expression is given in equation (17) below.

$$(17) \quad C_B = \$24{,}930 + \$3{,}140(R)$$

where

C_B is building replacement cost in dollars and R is 1,000 pounds of plant output per hour.

An annual charge of 8.9 per cent of replacement costs is applied to equation (17) above to give the annual fixed charge for depreciation, taxes, insurance, interest, and repairs.[1]

1/ These charges include depreciation 2.5 per cent; taxes 1 per cent; insurance 0.6 per cent; interest on investment 3 per cent (approximately 5.5 per cent of the undepreciated balance); and repairs 1.8 per cent--for a total of 8.9 per cent.

TABLE 16

Estimated Construction Cost of Concrete Wall and Concrete Floor (Ground Level), Frozen Lima Bean Processing Plants in Relation to Size of Building,[a] California, 1958

Item	Units	Unit cost	Total quantity[b]			Total cost		
			Plant A	Plant B	Plant C	Plant A	Plant B	Plant C
		dollars				thousand dollars		
Roofed area								
Grading	1,000 square feet	20	15.0	25.2	35.1	0.3	0.5	0.7
Floor	1,000 square feet	449	15.0	25.2	35.1	6.7	11.3	15.8
Walls:								
Exterior	1,000 square feet	1,723	8.2	10.1	11.9	14.1	17.4	20.5
Interior	1,000 square feet	618	1.0	1.6	2.4	0.6	1.0	1.5
Ceiling	1,000 square feet	395	0.6	1.7	2.7	0.2	0.7	1.1
Roof and frame	1,000 square feet	1,105	15.0	25.2	35.1	16.6	27.8	38.8
Doors:								
Swing	Each	74	6.0	6.0	8.0	0.4	0.4	0.6
Overhead	Each	247	4.0	6.0	8.0	1.0	1.5	2.0
Windows	Each	39	4.0	6.0	9.0	0.2	0.2	0.4
Heating	Each	100	1.0	1.0	2.0	0.1	0.1	0.2
Ventilation	Each	100	2.0	4.0	8.0	0.2	0.4	0.8
Subtotal						40.4	61.3	82.4
Paving and siding								
Railroad siding	Lineal feet	10	200.0	300.0	450.0	2.0	3.0	4.5
Paving	1,000 square feet	499	7.8	12.0	20.7	3.9	6.0	10.3
Subtotal						5.9	9.0	14.8
Total direct cost						46.3	70.3	97.2
Contingencies, 5 per cent of direct cost						2.3	3.5	4.9
Architectural and engineering fees, 2 per cent of direct cost						0.9	1.4	1.9
Contractor's overhead and profit, 16 per cent of direct cost						7.4	11.2	15.6
Total cost						56.9	86.4	119.6

a/ Excludes freezing and cold storage facilities, electrical wiring, and water piping.

b/ Quantities of each construction unit estimated from space requirements of plants of three different capacities. Plant A is designed for a maximum hourly capacity of 10,000 pounds packout; Plant B, 20,000 pounds; and Plant C, 30,000 pounds.

Source: Sammet, L. L., "Economic and Engineering Factors in Agricultural Processing Plant Design" (Ph.D. thesis, University of California, 1958), 434p.

$$(18)\quad AFC_B = \$2,219 + \$280(R)$$

Equations (17) and (18) were used to estimate total building investment replacement costs and annual fixed charges in relation to space requirements of plants of selected capacities. These costs are summarized in Table 17.

Electrical Power Distribution

Processing plants of identical floor space area may vary widely with respect to electrical power requirements because of differences in the power requirements of different types of equipment. For this reason, investment costs for electrical wiring are shown as a separate cost component and are not included as a part of the building costs developed above. Variable costs of electrical power inputs are included in the particular stage of operation to which they apply.

Costs of electrical-wiring systems used in this analysis are based upon engineering estimates of replacement costs. The initial step in the estimating procedure used was to determine power wiring and illumination requirements for a series of well-organized plants of different capacities. This involved drawing power and light circuit layouts showing the number and distribution of motors, light fixtures, and switchboards, together with motor horsepower ratings and wattage requirements for illumination. The data derived from these drawings provided the basis for estimating the quantities and types of equipment needed for each installation.

Costs of installation and materials were then estimated by applying current prices to the quantities of labor and materials required for electrical power distribution in each size of plant considered. The prices used in the development of labor and materials cost, including charges covering contingencies, profits, and fees, were obtained from electrical contractors. The replacement costs estimated in this manner were then related to plants of various size as measured by capacity output rates and summarized in Table 17. Investment replacement costs of power distribution systems--based on the costs given in the table and related to the plant capacity output rates--are given in the generalized expression below.

$$(19)\quad C_E = \$3,450 + \$171(R)$$

TABLE 17

Floor Space Requirements, Replacement Costs, and Annual Fixed Charges of Plant Building, and Electrical and Water Supply Systems in Relation to Capacity Output Rates, Lima Beans, California, 1958

	Plant building			Electrical system		Water supply system		Total	
Rate of output[a]	Roofed area[b]	Replacement cost[c]	Annual fixed charge[d]	Replacement cost[e]	Annual fixed charge[f]	Replacement cost[g]	Annual fixed charge[h]	Replacement cost	Annual fixed charge
pounds per hour	square feet	dollars							
5,000	10,025	40,630	3,619	4,305	382	4,600	410	49,535	4,411
10,000	15,050	56,330	5,019	5,160	457	6,900	615	68,390	6,091
15,000	20,075	72,030	6,419	6,015	532	9,200	820	87,245	7,771
20,000	25,100	87,730	7,819	6,870	607	11,500	1,025	106,100	9,451
25,000	30,125	103,430	9,219	7,725	682	13,800	1,230	124,955	11,131
30,000	35,150	119,130	10,619	8,580	757	16,100	1,435	143,810	12,811

[a] Index of plant size.

[b] Estimated from relation: $A = 5{,}000 + 1{,}005(R)$, where A is roofed area excluding freezing and cold storage facilities and R is 1,000 pounds plant output per hour.

[c] Estimated from relation: $C_B = \$24{,}930 + \$3{,}140(R)$.

[d] Estimated from relation: $AFC_B = \$2{,}219 + \$280(R)$.

[e] Estimated from relation: $C_E = \$3{,}450 + \$171(R)$.

[f] Estimated from relation: $AFC_E = \$307 + \$15(R)$.

[g] Estimated from relation: $C_W = \$2{,}300 + \$460(R)$.

[h] Estimated from relation: $AFC_W = \$205 + \$41(R)$.

In equation (19) the symbol C_E refers to investment replacement cost of power distribution while the symbol R refers to 1,000 pounds of plant capacity output per hour.

An annual charge of 8.9 per cent of replacement cost was used to cover depreciation, taxes, insurance, repairs, and interest.[1] Annual fixed charges of electric power distribution are obtained by applying this percentage to the expression given in equation (19) above. The result is given below:

$$(20) \quad AFC_E = \$307 + \$15(R)$$

In equation (20) AFC_E is the annual fixed charge of electric power distribution and R is as defined previously.

Water Supply System

The quantity of water delivered through the piping system of a given plant depends upon the gauge pressure at the source of the plant water intake; diameter, length, and age of piping; and number, size, and types of orifices and valves, etc.

Estimation of replacement costs of plant water supply systems parallels the procedure used in the estimation of electric power wiring. This involves the preparation of a number of piping layouts showing the number and distribution of equipment items, flumes, pumps, and personal service facilities together with estimated water use rates.[2] The size and quantities of industrial piping needed to supply plant water requirements with a given intake pressure were estimated from these layouts.[3] Costs of installation and materials were

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[1] These charges are allocated in the same manner as for buildings.

[2] With the plant layouts considered, standard equipment items are arranged in straight line fashion. Plant water mains are 18 to 20 feet above floor level, with tap-ins or drops averaging 15 feet each in length. Additional footage is provided for branch runs and drops to account for dispersement of boiler room, laboratory, and personal service facilities such as rest rooms and drinking fountains. Estimated water use rates and variable costs are presented in Table 12, page 51, of this report.

[3] Selection of pipe size was made so as to provide 25 pounds per square inch minimum pressure at equipment discharge points, with 60 pounds per square inch pressure in city distribution main.

then estimated by applying current prices to the quantities of labor and materials needed in each size of plant considered.[1] The investment replacement costs so estimated were then related to plants of various size as measured by selected capacity output rates. Costs estimated in this manner are summarized in Table 17. A generalized expression showing investment replacement costs of water supply systems in relation to plant capacity output rates is given in equation (21) below:

$$(21) \quad C_W = \$2,300 + \$460(R)$$

The symbol C_W refers to investment replacement cost of water supply systems of Lima bean plants, and R is 1,000 pounds of plant capacity output per hour.

The annual fixed charge of plant water distribution systems is obtained by applying an annual charge of 8.9 per cent to the above estimate of replacement costs. This includes amounts for depreciation, taxes, insurance, interest, and repairs that are identical with those applied to buildings and electrical power systems. Annual charges based on this percentage and the estimated replacement costs are summarized in Table 17. A generalized expression based on these costs is given in equation (22).

$$(22) \quad AFC_W = \$205 + \$41(R)$$

The symbol AFC_W refers to the annual fixed charge of plant water distribution systems, and R is as previously defined.

Summary of Building, Electrical Wiring, and Water Supply Costs

Total costs in this category are simply the sum of the costs of building, water, and electrical facilities. The totals as to investment cost and annual fixed charge for plants of selected capacity rates are given in Table 17 and are shown graphically in Figure 19.

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[1] The quantities and prices of construction inputs were derived from estimates obtained from commercial contractors on the basis of the specifications provided.

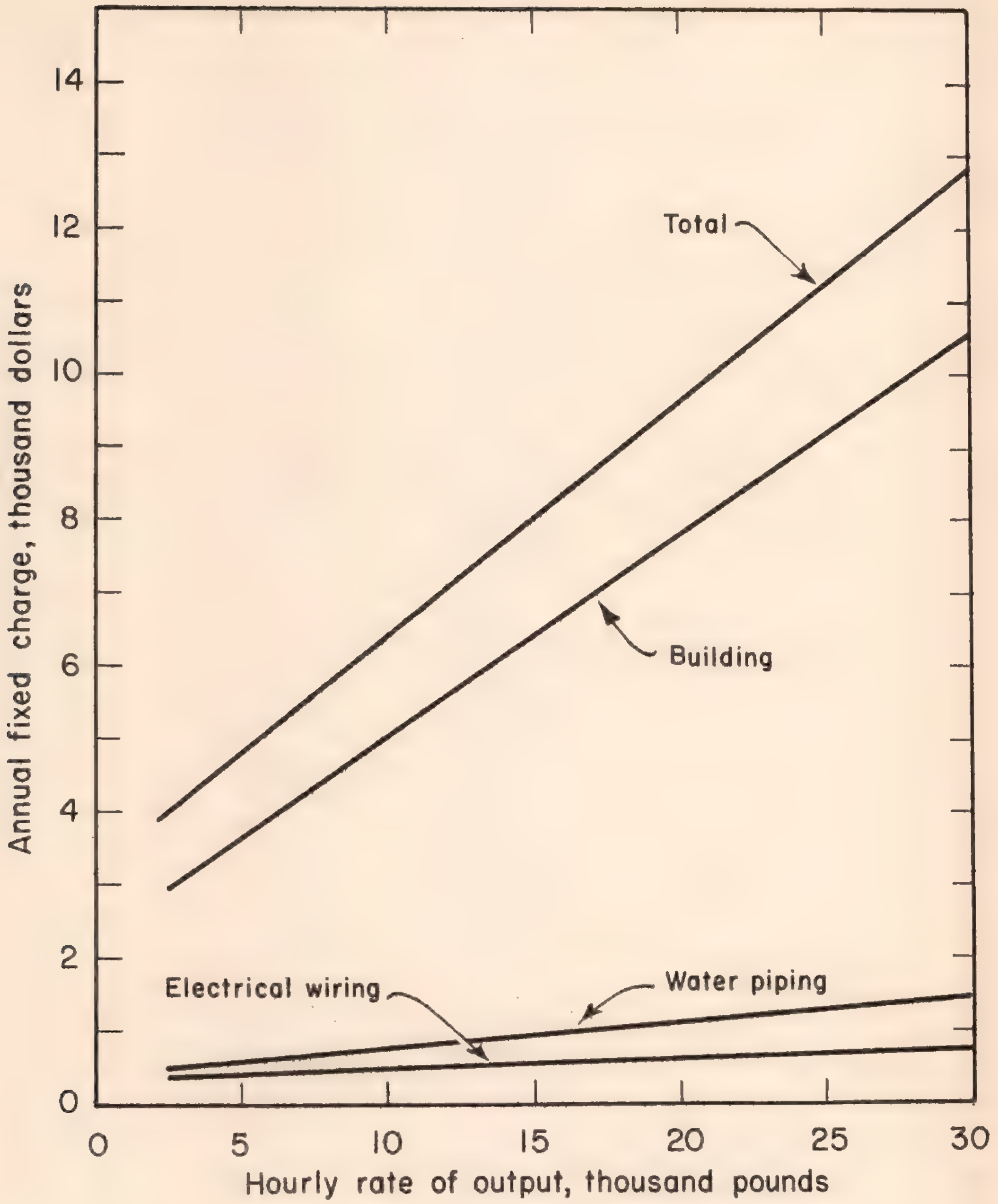

Figure 19. Annual Fixed Costs of Building and Electrical Power and Water Distribution Systems in Lima Bean Freezing Plants in Relation to Capacity Rate of Plant Output (Size of Plant), California, 1958.

Supervision and Miscellaneous Labor

Labor associated directly with a particular operating stage has been included in each stage analysis. There are several additional categories of general supervision and labor categories, however, that are not directly related to a specific operating stage. These include the plant superintendents; foremen; subforemen; foreladies; and quality control, utility, and cleanup workers. Some plants are also under continous U. S. Department of Agriculture inspection which requires the presence of a federal inspector during each operational shift.

Total annual costs of these general categories vary widely among plants, primarily in relation to the size of the operation and length of season. Data relating to these cost categories were obtained from accounting records of the firms studied. Analysis of these data resulted in the following generalized expression which relates the costs of supervision and miscellaneous labor to capacity output rate and hours operated per season:

$$(23) \quad TSC = \$2{,}800 + \$7.110(H) + \$1.240(R)(H)$$

where

TSC is total season cost of supervision and miscellaneous labor in dollars.
R is 1,000 pounds of plant output capacity per hour.
H is hours of plant operation per season.

Costs based on the above expression are shown graphically in Figure 20.

Administrative and Office Costs

The administrative and office cost component includes salaries of administrative office employees, plant managers, and field men. It also includes expenditures for professional services, office supplies, telephone, licenses, dues, subscriptions, and donations. It does not include selling costs.

Administrative and office costs are related to both size of plant and length of season. However, it was not possible to develop a precise relationship among these variables from plant record data. This was due to the difficulty of separating administrative costs attributable to Lima bean processing in multiple-product plants and because of the multiple nature of the

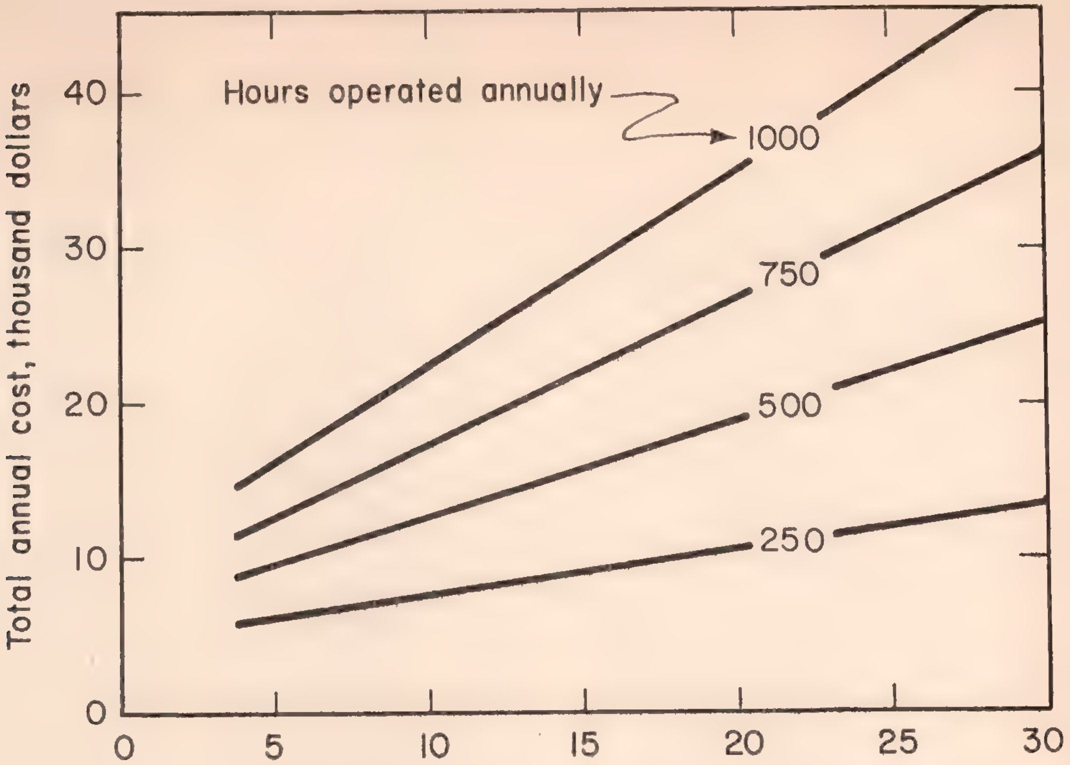

Figure 20. Total Annual Costs of Supervision and Miscellaneous Labor in Plants Processing Lima Beans by Freezing Related to Length of Season and Rate of Plant Output, California, 1958.

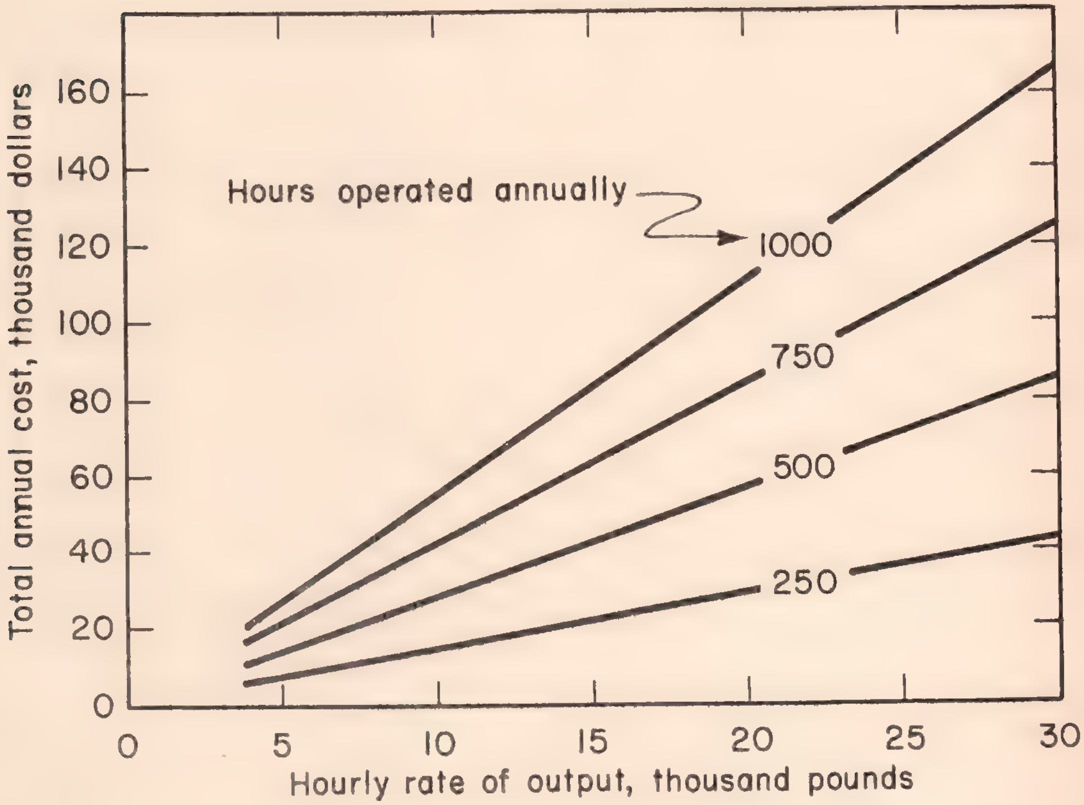

Figure 21. Total Annual Costs of Plant Administration in Relation to Length of Season and Rate of Plant Output in Plants Processing Lima Beans by Freezing, California, 1958.

duties performed by some administrative personnel. Consequently, total administrative costs--drawn from an analysis of accounting record data of plants cooperating in this and other studies--were developed by applying a constant unit cost based on the allocation of these costs to various products on a total season volume basis. This relation is given by equation (24) below and is graphically depicted in Figure 21.

$$(24)\quad TSC = \$5.51(R)(H)$$

where

TSC is total season cost of plant administration in dollars.
R is 1,000 pounds of plant capacity output per hour.
H is hours of plant operation per season.

Miscellaneous Equipment

Equipment items associated with a particular operating stage have been included in the estimates of stages costs presented in earlier sections. Many equipment items such as repair, fabricating, laboratory, and housekeeping equipment are not assignable to particular operating stages and are considered as comprising part of general plant overhead. These are grouped together and summarized in Appendix A, Table 1, for inclusion in total plant costs of processing Lima beans for freezing. Total season costs of these equipment items--related to plant output and length of season--are represented in the equation below. Estimation of these costs is based on annual fixed charge of 16.5 per cent of the equipment replacement cost and a variable charge of 0.5 per cent of replacement cost per 100 hours operation for variable repairs and maintenance.

$$(25)\quad TSC = \$1,072 + \$9.00(R) + \$0.3250(H) + \$0.1300(R)(H)$$

where

TSC is total season cost of miscellaneous equipment, and R and H are as defined above.

The cost relations stated in the above expression are graphically illustrated in Figure 22.

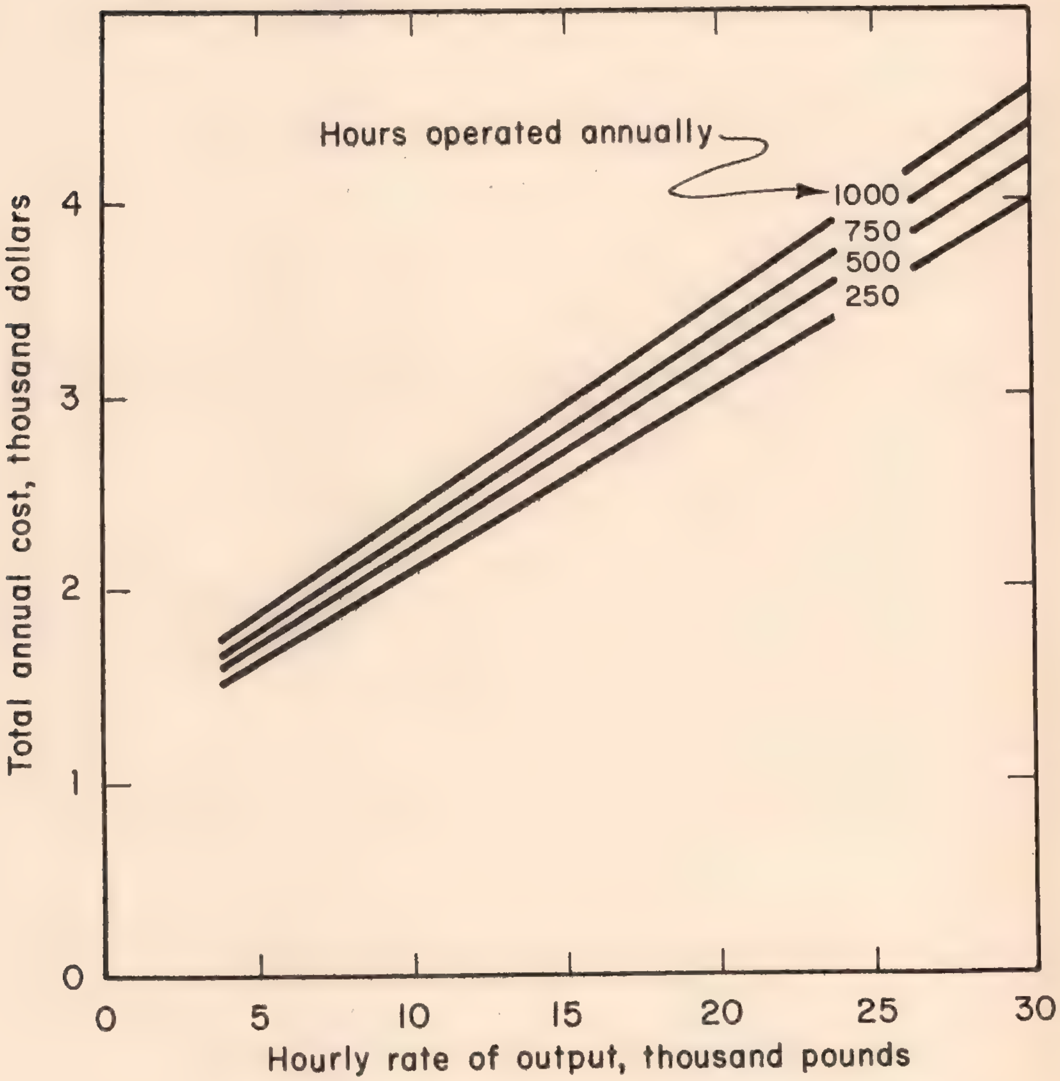

Figure 22. Total Annual Costs of Miscellaneous Equipment in Plants Processing Lima Beans by Freezing Related to Rate of Plant Output and Length of Season, California, 1958.

TOTAL FIELD ASSEMBLY AND PLANT COST

In the preceding sections total costs in relation to volume of output and other conditions of plant operation were developed for each of several operating stages. In this section the cost relationships for individual stages as well as general costs not associated with specific stages are combined into total costs for the entire operation.

Total plant cost is affected by the rate of output, length of operating season, style of pack, the manner in which field and plant operations are integrated, the wage rates paid, and other factors. The effects of variations in the more important of these factors have been considered specifically in the stage-cost analyses. Fixed values were taken for certain other factors considered unlikely to vary enough under ordinary circumstances to have a significant effect on total costs. Specifications relating to such factors--most of which have been previously discussed--are summarized below.

1. Plant size is defined in terms of capacity output rate. Specific consideration is given to six different plant capacities varying in 5,000 pound increments over the range 5,000-30,000 pounds of raw product "throughput" per hour.[1/]

2. A maximum of eight hours temporary storage (with ice) is allowed between vining and processing and is assumed to have no measurable affect on quality.

3. In each plant considered, packaging and casing equipment are provided for each style of pack--retail, institutional, and bulk--with capacity for handling the entire plant throughput in any single style of pack.

4. Repackaging operations were not considered.

5. Straight-time wage rates as specified in the 1958 Collective Bargaining Agreement Between Frozen Food Processors and the California State Council of Cannery Unions were used in the development of in-plant labor costs. These

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[1/] "Throughput" is the rate of flow of raw product that is handled by the labor and equipment of each operating stage. In-process losses in product weight due to maturity grade separation are partially or wholly offset by weight gains attributable to water absorption and are assumed to have negligible effect on the selection of processing equipment based on capacity. The major effect of quality, as measured by overmature and defective beans, is on labor requirements of the visual inspection and manual quality separation stage.

rates were increased 6 per cent to allow for employer payroll contributions. Field labor costs used in estimating costs of vining and field assembly operations were based on typical wage rates observed among plants cooperating in the study.

6. Selling costs and storage costs beyond the first month were omitted.
7. The costs of raw product are not included.

Separate Planning Costs for Field and Plant Activities

Planning cost equations that were developed in preceding sections of this analysis are summarized in Table 18. The operating stages are listed in the first column of the table, while each of the remaining columns relates to a variable used in deriving the planning equations relating to the separate operating stages and cost components. Individual planning cost equations taken from the stage analyses presented earlier--can be read directly from the table by applying appropriate coefficients given in the body of the table to the variables listed in the column headings. For example, the cost equation for vining read from the first line of Table 18 is: $TSC_v = \$3.929 + \$2,633(R) + \$0.3691(H) + \$7.99(R)(H)$; in which TSC_v represents total season vining cost, and the variable (R) and (H) are as described previously.

Planning cost equations for plant and field operations are obtained by aggregating the equations representing costs of the individual stages and cost components.[1] Thus, the planning cost equation for total field and assembly operations is obtained by summing the entries on lines 1 and 2 of Table 18. This gives:

$$(26)\quad TSC_a = \$3,929 + \$2,633(R) + \$0.3691(H) + \$7.99(R)(H) + \$1.40(\log_{10}D)(R)(H)$$

The planning cost equation for the total in-plant operation is similarly obtained by summing the entries in lines 1 to 12 of Part B of Table 18. This expression, read from the last line of Table 18, is given in equation (27) below:

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[1] The individual operating stages were so defined as to be independent with respect to stage costs. Total plant cost relationships then are given by simple summation of stage-cost relationships.

TABLE 18

Summary of Planning Cost Equations for Operating Stages and Cost Components in Field Assembly and Processing Operations for Plants Processing Lima Beans for Freezing, California, 1958

Operating stages and cost components	Variables[a]								
	Constant term[b]	(R)	(H)	(R)(H)	Log D (R)(H)	(R)(H)(P)	$(H_r)(R)$	$(H_i)(R)$	$(H_b)(R)$
	coefficients or multipliers expressed in dollars								
A. Field or assembly costs									
1. Vining	3,929	2,633	0.3691	7.99					
2. Transportation to plant					1.40				
Total field or assembly costs	3,929	2,633	0.3691	7.99	1.40				
B. In-plant costs									
1. Receiving, initial cleaning, and quality grading	1,892	320	4.5882	0.8494					
2. Blanching and second-quality grading	1,293	187	5.6773	0.2238					
3. Visual inspection and manual quality grading	149	32	8.6500	1.5100		0.1110			
4. Packaging	4,345	856					24.730	14.480	4.590
5. Variable water costs	166	15	0.1872	0.5380					
6. Casing	489	67					7.952	4.712	
7. In-plant transportation of cased goods and packaging materials	425	48	1.0800	0.1300					
8. Freezing				8.3000					
9. Plant investment costs									
a. Buildings	2,219	280							
b. Electrical wiring	307	15							
c. Water piping	205	41							
10. Supervision and miscellaneous labor	2,800		7.1100	1.2400					
11. Plant administration				5.5100					
12. Miscellaneous equipment	1,072	9	0.3250	0.0130					
Total in-plant costs	15,353	1,870	27.6177	18.3142		0.1110	32.682	19.192	4.590

a/ The variables of the planning cost equation are defined as follows:

(R) = 1,000 pounds of plant output capacity per hour.

(H) = number of hours of plant operation per season.

(R)(H) = total season volume obtained by multiplying 1,000 pounds of plant hourly output times the number of hours operated per season.

Log D (R)(H) = logarithm of the distance from viners to plant multiplied by total season volume (R)(H).

(R)(H)(P) = total season volume multiplied by the percentage of grade-out remaining after mechanical quality separation and must be manually graded on an inspection belt.

$(H_r)(R)$ = number of hours operated per season packaging retail style times the plant output rate (R) as defined in this footnote.

$(H_i)(R)$ = number of hours operated per season packaging institutional style times the plant output rate (R) as defined in this footnote.

$(H_b)(R)$ = number of hours operated per season packaging bulk style times the plant output rate (R) as defined in this footnote.

b/ Represents the fixed annual charge.

$$(27) \quad TSC_p = \$15,353 + \$1,870(R) + \$27.6177(H) + \$18.3142(R)(H) + 0.1110(R)(H)(P) + \$32.682(H_r)(R) + \$19.192(H_i)(R) + \$4.59(H_b)(R)$$

Equation (26) can be used to estimate total field costs—vining and assembly—for any given rate of vining output, number of hours of vining operation per season, and distance of haul from viners to plant. Equation (27) can be used to estimate total in-plant processing costs for any given rate of plant output, number of hours of plant operation per season, percentage of manual grade-out, and hours spent in packaging each style of pack. To illustrate the procedure, consider a plant that has a capacity output of 10,000 pounds per hour; operates 250 hours packaging retail style and 250 hours packaging institutional style for a total season of 500 hours; and maintains a brine concentration in mechanical quality graders such that manual grade-out percentage averages 5 per cent. Assume further that the vining capacity output rate is also 10,000 pounds per hour and that the average distance from viners to plant is 10 miles. Based on these assumptions, the variables appearing in equations (26) and (27) have the following values:

$R = 10$
$H = 500$
$D = 10$
$P = 5$
$H_r = 250$
$H_i = 250$
$H_b = 0$

Substituting these values in the total cost equations given above gives total annual costs of $77,394 for field and assembly operations and $271,893 for in-plant processing.

Average cost is found by dividing total annual cost by the number of pounds packed. In the above example, the total number of pounds packed during the season is the product of the rate of hourly output and the number of hours operated, or 5 million pounds. Dividing this amount into estimated total costs gives a unit cost of field and assembly operations of 1.548 cents per pound and an average cost of in-plant processing of 5.438 cents per pound.

Combined Planning Costs for Field and Plant Activities

The development of combined processing costs reflecting efficient organization requires finding the least-cost combination of hours operated per season and hourly output rates of field and plant operations. The integration or programming of vining and plant facilities and operating hours so as to achieve lowest total annual cost for handling any given season volume of Lima beans is discussed in this section.

Integration of Field and Plant Operations

Institutional and operating restrictions--such as collective bargaining agreements, custom, the length of harvest season, and the number of hours it is possible to operate per day--place limits on the number of combinations of capacity output rates and hours of operation but allow much variation. An additional consideration is uncertainty in some aspects of scheduling field and plant activities. This requires flexibility in the design of plant and vining facilities that will give relatively low costs over a range of output rates and operating hours near the least-cost level.

While all possible combinations of plant and field output rates and operating hours are not considered, four important alternatives are presented in Figure 23. Two sets of curves are shown--one based on 30 and the other on 40 days of operation per season. Each of the cost curves shown in Figure 23 represent unit costs of processing Lima beans for freezing with least-cost techniques for selected combinations of field and plant capacity output rates and daily operating hours. In the cases presented, a maximum of eight hours temporary storage (with ice) is allowed between vining and in-plant processing; and this is assumed to have no measurable effect on quality. It is also assumed that daily operating hours and rates of output of vining and plant operations are such that the total volume vined per day is equal to the total volume processed. In recognition of time lost daily in lunch periods, changing shifts, cleanup, equipment servicing, rest periods, and other delays, a maximum of 16 hours operation per day was applied in these examples. This conforms closely to the maximum daily operating hours observed in plants cooperating in the study.

The four cases presented are (1) a single 8-hour shift per day in both plant and vining operations; (2) two 8-hour shifts of plant and vining operations per day; (3) one 8-hour shift of plant operations per day with two 8-hour shifts of vining; and (4) two 8-hour shifts of plant operations per day with one 8-hour shift of vining. The least-cost combination of season volume, hours

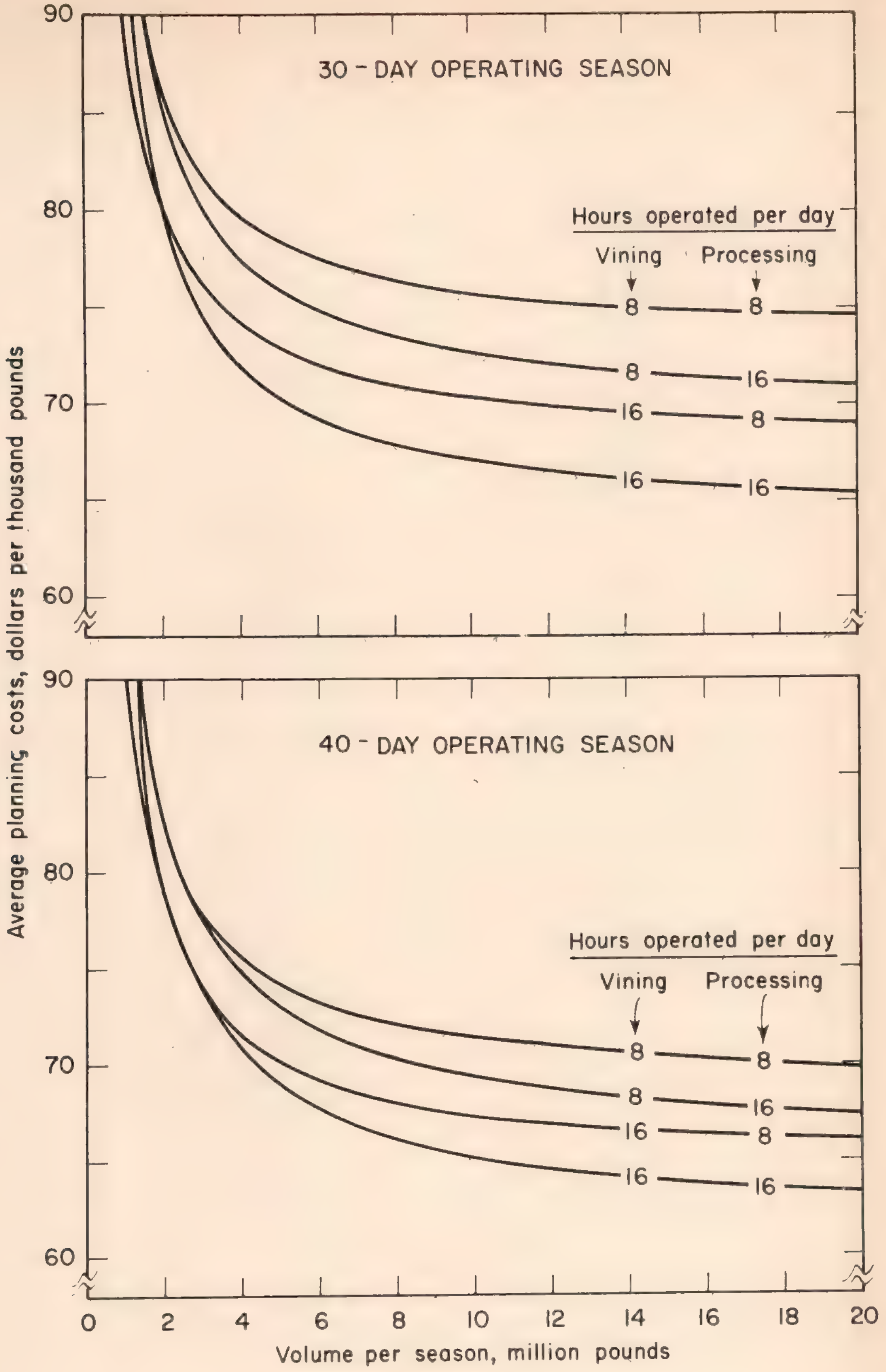

Figure 23. Relation of Average Planning Costs to Season Volume With Four Levels of Restrictions on Daily Plant and Vining Operations in Processing Lima Beans for Freezing. California, 1958.

of operation per season, and output capacity rates were worked out for each case.[1] The cost curves presented for these four cases are based on: season packout consisting of 70 per cent in retail cartons, 20 per cent in institutional cartons, and 10 per cent in bulk bags or cases; length of haul (viners to plant)--10 miles; and manual grade-out--5 per cent. Specification of other values for these variables would not materially affect the general relationships developed.

Several general characteristics of average cost behavior as illustrated in Figure 23 are noted. First, with any given pattern of daily operating hours and length of season, total season hours are fixed and so differences in total season volume necessarily involve changes in scale of plant as measured by planned capacity output rates. Consequently, each point on a particular curve represents average cost with a different plant.[2] With a given length of season and over a wide range of plant capacities, unit costs decrease as plant capacity increases. This reduction in unit costs associated with increased scale of output results from more effective utilization of supervision and other partially fixed labor inputs and the substitution of various cost reducing techniques in the larger plants. Second, plant capacity rates necessary to achieve any given season volume decrease as hours of operation per season increase. As planned capacity rate with a fixed season volume decreases, investment cost and the corresponding annual fixed charge are smaller which tends to give lower unit fixed costs. As planned capacity is decreased, however, some of the cost advantages of increased scale are lost and this tends to give increased costs per unit.

Thus, the behavior of unit planning costs varies with both length of season and capacity output rates, and efficient organization of plant and field operations calls for balancing the net cost effects of scale of plant and operating hours. The average cost curves illustrated in Figure 23 reflect the effects described above. Except with relatively small season volumes, average planning costs with any given season volume and combination of vining and processing plant hours are lower with a 40-day than a 30-day season. Unit costs

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[1] The least-cost combination of hours and rates for any given season volume is obtained by minimizing the planning equations representing total annual costs of vining and plant operations--equations (26) and (27)--subject to appropriate constraints on maximum daily operating times and temporary storage allowances for a given length of season. For technical details of the solution, see Appendix B, page 101.

[2] "Plant" refers to both vining and in-plant processing facilities.

are lowest over a wide range of season volumes when both vining and plant facilities are planned for a two-shift operation per day, the maximum daily operating time considered. As total season volume becomes smaller, however, the effects of decreasing scale become more important. With a 40-day season, for example, and for total season volumes below three million pounds, Figure 23 shows that lowest costs are achieved by operating two vining shifts and one plant shift per day, so that vining capacity rate of output is one-half that of the plant. The effect of scale is much more pronounced in regard to plant than vining operations, and this explains the shift in the low-cost combinations of daily vining and plant hours illustrated in the figure.

For the range of operating conditions specified, the above demonstrates that efficient handling of any season volume would call for plant and vining facilities of capacities such that operations were for the maximum number of hours available during the season except in cases where the season is relatively long and the total season volume relatively small. In the cases excepted, costs are lower with planned plant capacity greater than that of the vining facilities, and minimum cost operation would require that hours of vining per day exceed hours of plant operation.

Problems of Flexibiltiy

One of the more important problems in processing Lima beans for freezing is how to adjust economically to considerable fluctuations in daily volume of product during the operating season. In addition to variations in daily volume, there are also variations in the proportions of Lima beans packed in various size containers and grades.

Two types of adjustment to variations in daily volume are used. In one, hours of daily operation may be varied and the plant and vining facilities operated at their most efficient rate of output with little change in cost rates, except where overtime pay is required. A second type of adjustment is applicable where there is a large reduction in daily volume relative to total capacity. The total labor force then might be reduced and the plant operated at less than capacity output rates. This is particularly true if collective bargaining agreements and the maintenancw of satisfactory labor relations require that workers be paid for a minimum number of hours per day.

Large fluctuations in the volume of product received as well as daily variations in the proportions of Lima beans which must be packed in various size containers and grades are best handled in plants designed to operate with some degree of flexibility. A considerable amount of flexibility has been provided in the design of plants synthesized in this study. For example,

inclusion of facilities for temporary storage prior to the blanching operation provides some insurance against hour-to-hour fluctuations in plant receipts. Also, large variations in the proportions packed in the various size containers and grades are allowed for by providing filling and casing equipment capable of handling any given plant output in either retail, institutional, or bulk containers. Moreover, the values and standards on which the planning cost equations for specific operating stages are based are themselves "averages"which permit small ranges of variation around any given rate of output.

Comparison of costs as developed above with those in plants lacking provision for flexibility in output rate will indicate the extent to which costs are affected by incorporation of this feature in the plant designs used in this study. Calculations for the constant-rate plants may be made easily by adjusting the results already given for deletion of special equipment required to provide flexibility. This involves minor adjustments in annual fixed charges for filling and casing facilities, for temporary storage of incoming raw product, and for building space. These adjustments reduce costs below the levels given above by less than 1 per cent and would not materially affect the cost relationships indicated in this report.

The Planning Equation for Combined Field and Plant Processing Activities

From the preceding demonstration, it appears that over a wide range in season volumes, least-cost operation occurs with full-time daily operation—that is, 16 hours per day—in both field and plant. In the range of small season volume where this is not true, total costs with alternative combinations of field and plant hours differ by only a small amount from the level with full-time daily operation. This means that a close approximation to results based on least-cost combination of field and plant hours may be obtained if full-time daily operation in both these areas is assumed through the entire volume range considered. Since this assumption greatly simplifies the estimation of combined field and plant costs, it is applied in the analysis which follows. It permits the formation of planning cost equation for the combined operations by simple summation of the planning cost equation for field (equation 26) and plant operations (equation 27). The result is given below in equation (28):

$$(28) \quad TSC_{(A+P)} = \$19.282 + \$4{,}503(R) + \$27.9868(H) + \$26.3042(R)(H) + \$1.40(\log_{10} D)(R)(H) + \$0.1110(R)(H)(P) + \$32.682(H_r)(R) + \$19.192(H_i)(R) + \$4.590(H_b)(R).$$

The variables (R), (H), (D), (P), etc., are defined in Table 18, page 79.

Average cost per1,000 pounds pack-out is obtained by dividing the costs estimated in equation (28) above by the total season volume.

Equation (28) can be used to estimate total and average costs with efficient field and plant organization for any given size of plant, length of operating season, style of pack, percentage manual grade-out, and distance of haul from viners to plant. In the discussions to follow, use will be made of this equation to demonstrate how variations in the above variables affect total and average costs of processing Lima beans for freezing.

Economies Related to Size of Plant and Length of Season

The effect of size of plant (rate of output) and hours operated per season on total and average planning costs will be illustrated for plants operating under the following conditions: average distance of haul (viners to plant) is 10 miles; manual grade-out averages 5 per cent; 70 per cent of the total season volume is packed in retail cartons; 20 per cent in institutional cartons; and 10 per cent in bulk bags or cases. Estimates of total and average costs are obtained by substituting these values in equation (28) for each length of season and rate of output considered. The planning costs so computed are shown in Figures 24 and 25 for plants operating under the conditions specified. The general relationships presented would be approximately the same, however, if the variables were specified at different values.

The rate of reduction in average planning cost as the rate of output (size of plant) increases is shown in Figure 24. The curves in the figure show that average cost drops rapidly—for any given length of season—as the size of plant increases. The decrease in average cost as plant size increases is primarily due to more effective use of supervision and other partially fixed general labor costs and the substitution of various cost reducing techniques in the larger plants. The figure also shows that major cost-reduction possibilities through increased scale of operations are in plants of relatively low capacity and that advantages of increased scale are relatively small in plants above 20,000 pounds per hour capacity. Under the conditions assumed and with an operating season of 500 hours, for example, average cost for a plant operating at a capacity rate of 5,000 pounds per hour falls approximately $2.66 with each increase of 1,000 pounds in planned capacity. At a plant capacity of 10,000 pounds per hour, average cost falls approximately 66.5 cents with each 1,000 pounds increased capacity, and at 20,000 pounds per hour this figure is only 16.6 cents per 1,000 pounds added capacity.

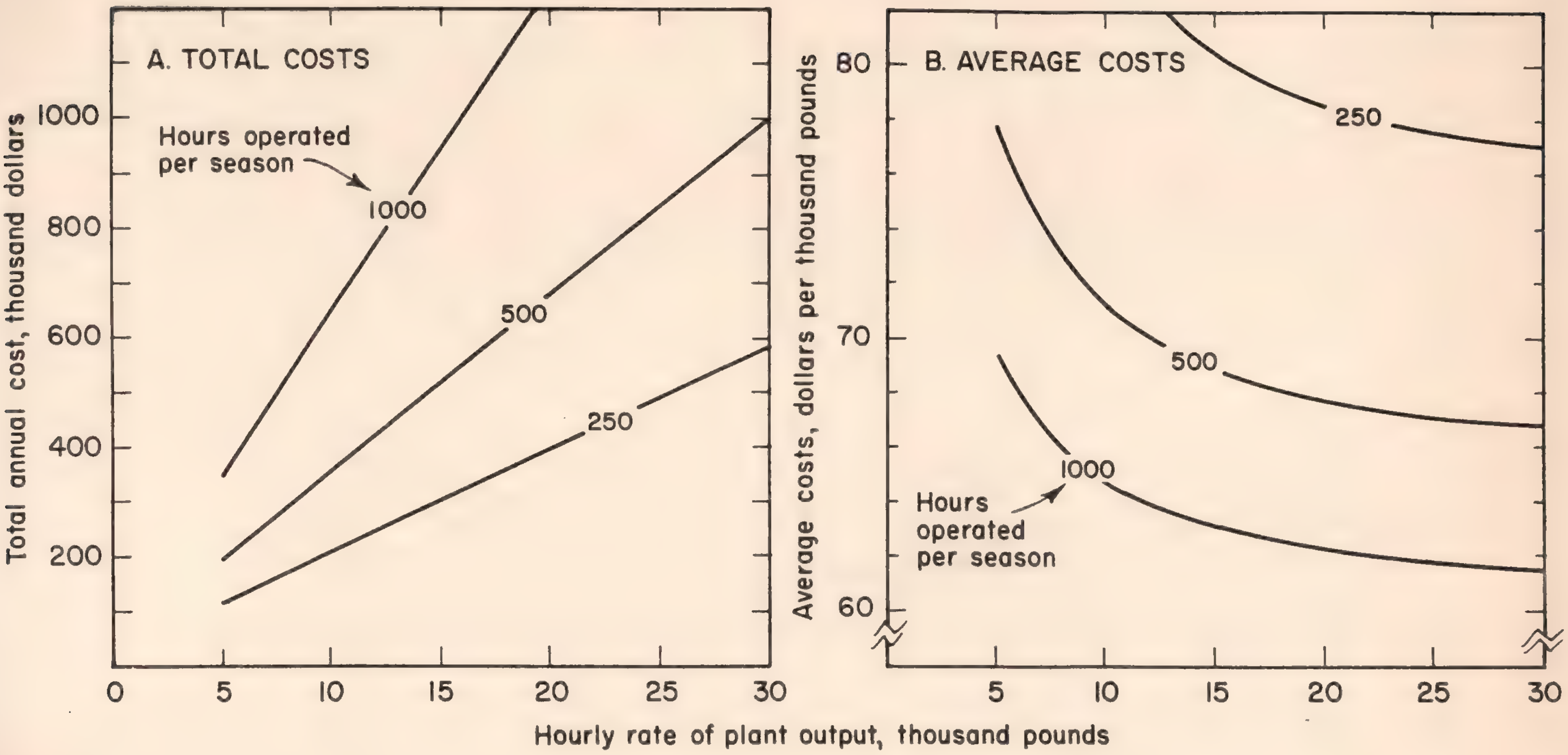

Figure 24. The Effect of Size of Plant (Capacity Rate of Output) on Total and Average Planning Costs for Three Lengths of Season, California, 1958

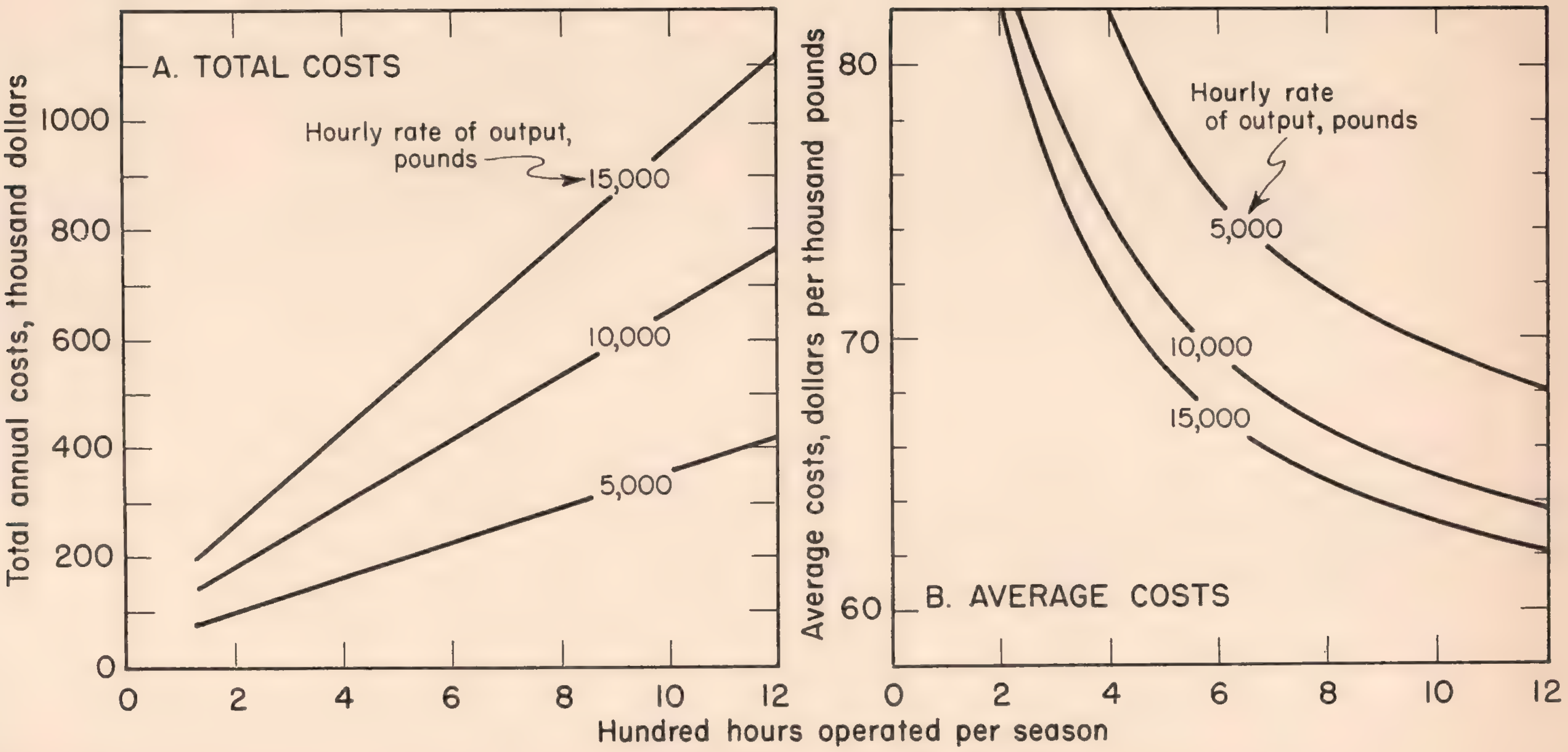

Figure 25. The Effect of Length of Operating Season on Total and Average Planning Costs for Three Sizes of Lima Bean Freezing Plants, California, 1958

Figure 25 demonstrates that average planning costs decrease as length of season--with a given capacity output rate--is increased and the annual fixed charge spread over a larger total volume of output. For any given capacity output rate, substantial reductions in average cost are indicated as the length of season is increased from 200 through 1,000 hours. However, economies associated with increased length of season become relatively less important for seasons in excess of 750 hours. To illustrate the magnitude of the effect of increased hours on average unit cost, let the capacity output rate be fixed at 10,000 pounds per hour--other specifications remaining as set forth in the beginning of this section. With a season of 250 hours, each increase of one hour reduces average cost by 10.3 cents per 1,000 pounds. With a 500-hour season, the rate of reduction is 2.6 cents with each added hour, while at 750 hours the rate of decrease in average cost is only .75 cent per 1,000 pounds with each additional hour of operation. Figure 25 and the preceding discussion indicate that economies associated with increased hours of operation per season can be relatively large. A substantial portion of such savings, however, cannot be realized in some bean-producing areas because of the short harvest season. This situation may be relieved by processing other products maturing in other periods and using the same types of equipment. Under favorable circumstances with respect to raw product procurement and sales, for example, frozen peas will serve this purpose in many California plants.

The Effect of Distance of Haul

Truck hauling charges in relation to distance were presented in an earlier section of this report wherein it was shown that the cost rate per 1,000 pounds hauled tends to level off as distance from the plant increases. The effect of distance of haul on average planning costs will be illustrated for plants operating under the following conditions: length of season is 500 hours; percentage manual grade-out averages 5 per cent; and 70 per cent of the total season volume is packed in retail cartons, 20 per cent in institutional cartons, and 10 per cent in bulk bags or cases. Estimates of average unit costs are obtained by substituting these values for the variables in equation (28) and calculating the average planning cost for each length of season and distance of haul considered. Average planning costs so computed in relation to selected lengths of haul are illustrated in Figure 26 for plants operating under the conditions assumed. The figure shows that hauling charges have a relatively small effect on average planning costs for distances up to 100 miles.

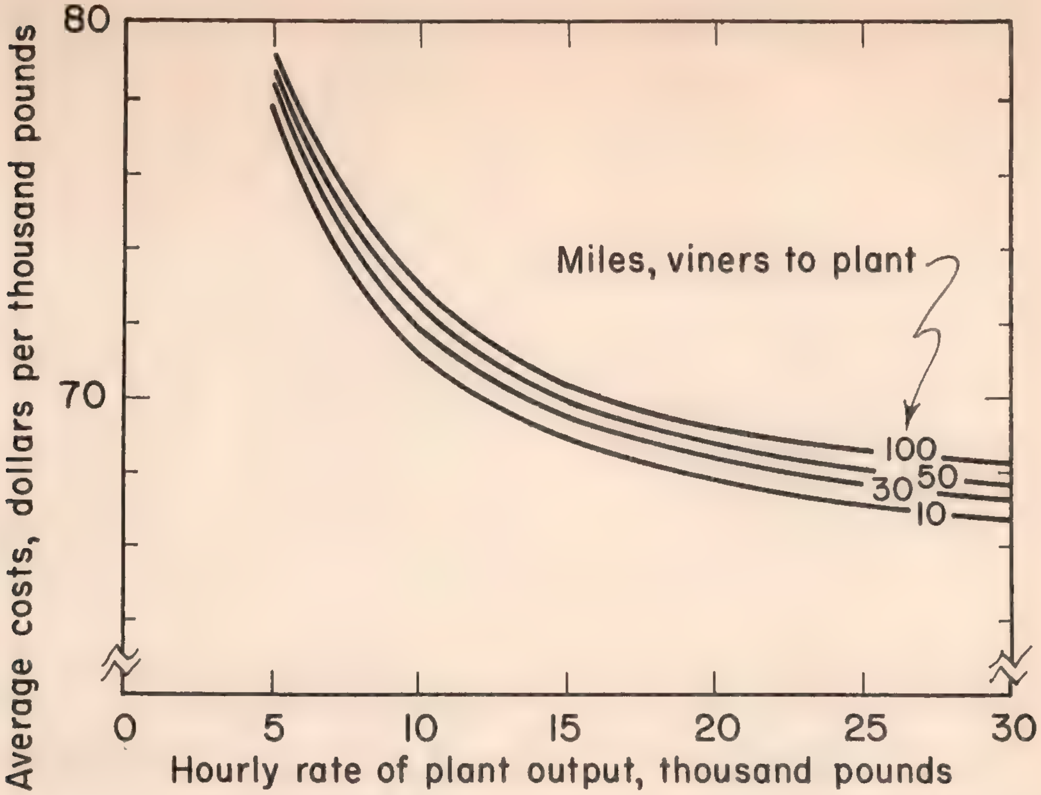

Figure 26. The Effect of Distance of Haul on Average Planning Costs in Relation to Selected Lengths of Haul and Capacity Rates of Output in Lima Bean Freezing Plants Operating 500 Hours Per Season, California, 1958.

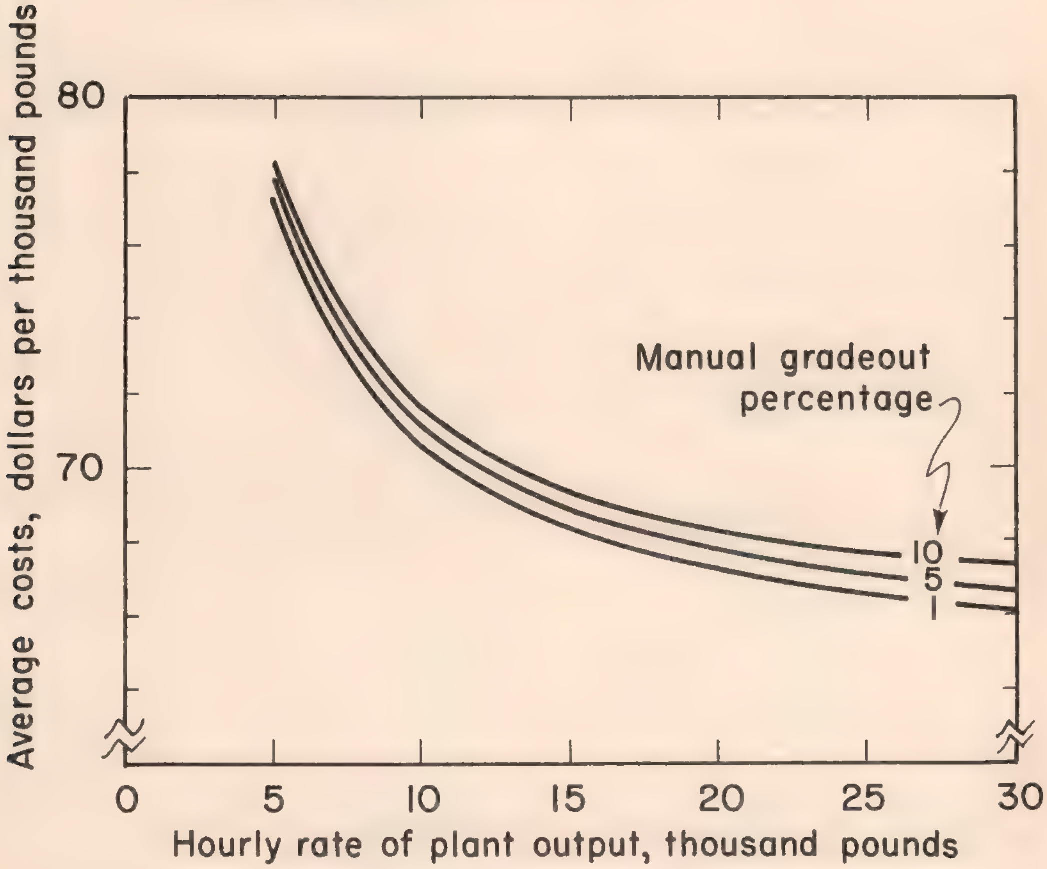

Figure 27. The Effect on Average Planning Costs for 1, 5, and 10 Per Cent Levels of Manual Grade-Out in Lima Bean Freezing Plants Operating 500 Hours Per Season, California, 1958.

However, some additional costs associated with increases in the length of haul were not specifically evaluated and are not shown in Figure 26. These include increased costs related to the more elaborate in-field cleaning and icing operations that must be performed as length of haul increases in order to avoid losses in grade yield and recovery.

Effect of Percentage Manual Grade-Out

The effect of the level of manual grade-out percentage on average planning costs can be determined with calculations based on equation (28) similar to the above. This is illustrated in Figure 27, which gives average unit costs with 1, 5, and 10 per cent manual grade-out.[1/] Increased cost resulting from increased numbers of defective and overmature beans that must be manually removed to make a particular grade specification is largely controlled by the effectiveness of mechanical quality-grading equipment. Losses in grade yield brought about by improper balancing of mechanical and manual quality grading could be substantial, however, and are not reflected in Figure 27.

Effect of Style of Pack

The proportion of total season volume packed in various size containers has an important effect on total and average planning costs. Figure 28 illustrates this effect for plants packing various percentages of their total season volume in retail, institutional, and bulk styles. The curves in Figure 28 are based on costs computed from equation (28) with the variables specified as follows: distance of haul averages 10 miles; an operating season of 500 hours; and percentage of manual grade-out average 5 per cent. The figure shows that total and unit costs--for a given capacity rate of output--increase substantially as the proportion of total season volume packed in retail cartons increases. This is primarily due to higher costs of retail packaging materials. The heavy lines in Figure 28 define upper and lower cost ranges as proportions of season volume packed vary from 100 per cent bulk style to 100 per cent retail style.

[1/] Other specified values of the variables in equation (28) are as in the preceding examples: 500 hours operated per season--distance of haul 10 miles; and 70, 20, and 10 per cent of the total season is packed in retail, institutional and bulk styles, respectively.

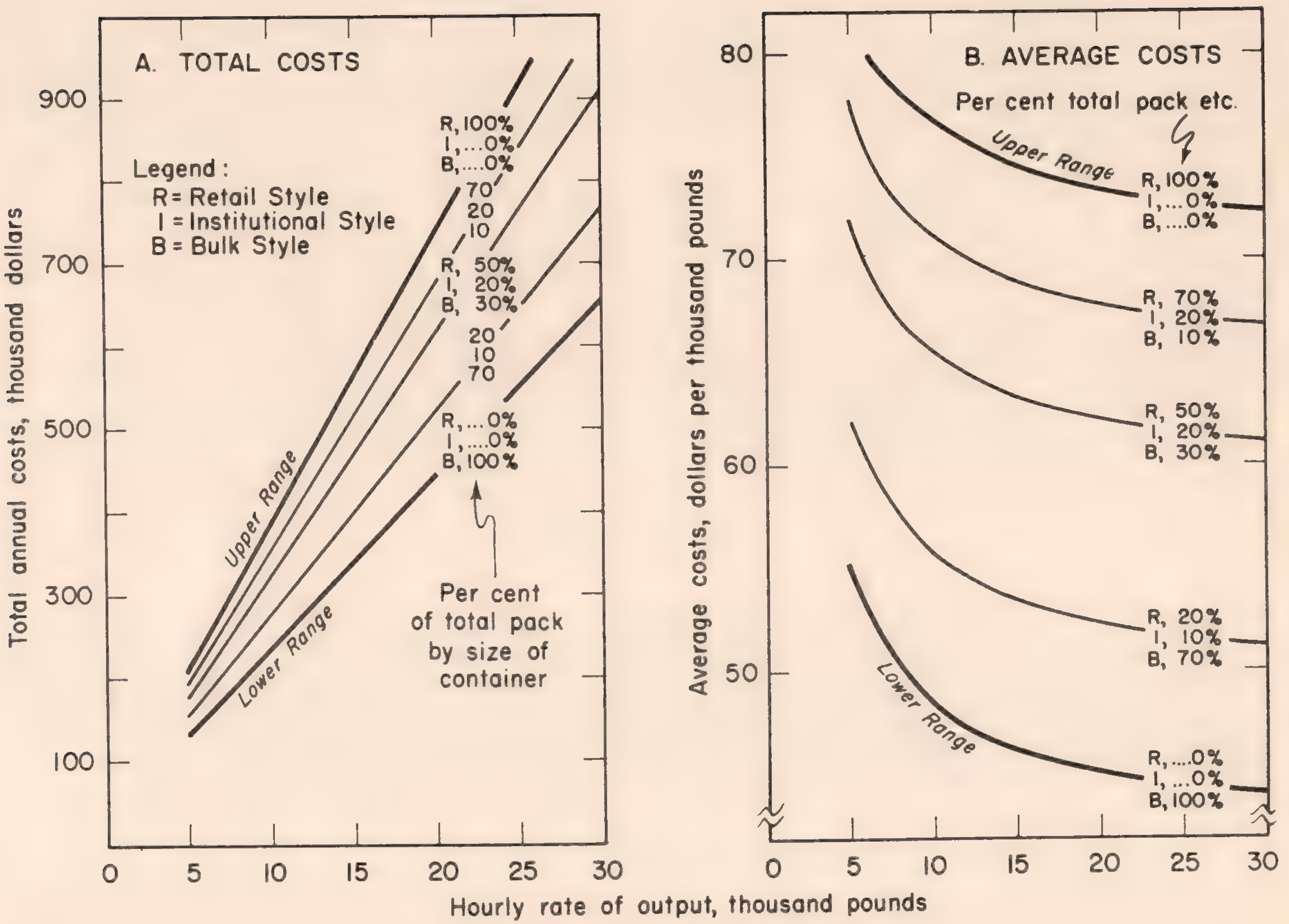

Figure 28. Total and Average Planning Costs Lima Bean Freezing Plants Packing Different Percentages of Retail, Institutional, and Bulk Styles for a 500 Hour Operating Season. California, 1958.

The cost relationships discussed above and illustrated in Figures 24 through 28 have been based on selected values of the variables comprising the expression of total annual planning costs given in equation (28). Total annual and average planning costs with conditions more closely approximating circumstances of individual interest may be calculated by specifying values for the variables other than those specified in this discussion. As the allocation of unit costs among the various styles and grades may be accomplished by several different procedures, meaningful estimates depend primarily upon the individual plant and local conditions. Therefore, no attempt has been made to allocate total and unit costs synthesized in this study to the various styles and grades.

SUMMARY

The major objectives in this report are to: (1) develop estimates of the total cost of processing frozen Lima beans with efficient crew and equipment organization; (2) determine a basis for integrating field and plant operations that will minimize total field and plant costs; (3) show how costs are affected by variations in such factors as scale of operation, length of operating season, distance of field-to-plant haul, per cent of manual grade-out, and proportions packed in different styles of pack; and (4) present this information in such a way as to indicate which of alternative methods in certain operating stages are most economical in the production of given annual volumes of output.

For convenience in analysis, field and plant operations are classified into ten operating stages and four general cost components (page 5). Engineering and economic data pertaining to individual operations are used to estimate for each plant operating stage the quantities and costs of labor, equipment, and other services required in relation to selected rates of plant output. The stage-cost estimates are made terms of variable costs per hour of plant operation and annual fixed costs for equipment and other services. These costs are used to estimate within each stage the total season cost with different lengths of operating season. Comparison of such stage-cost estimates for different methods indicates the least-cost method, and the aggregation of stage costs thus selected provides a basis for estimating season plant cost for the entire field and plant operation. Results of this procedure that indicate the effects of a wide range of operating conditions are presented both graphically and in terms of "planning cost equations."

Studies of alternative methods in particular plant stages gave the following indications as to least-cost method.

In field vining four methods—classified according to their degree of mechanization—are analyzed in relation to capacity rates of vining output and length of operating season. These include three methods of stationary vining and one method of mobile vining. Among the stationary vining methods, the most mechanized method—Method C—has lower annual costs than the others over all ranges of capacity and length of season considered. Mobile vining becomes the most economical method as the length of operating season increases beyond 500 hours and the annual fixed charge is spread over a larger total annual volume of output.

Bulk handling and bin handling are the two methods analyzed in connection with the receiving, initial cleaning, and quality-grading stage. Studies of these methods failed to show any significant cost difference between them.

Four methods of casing are studied in relation to estimated quantities and costs of labor and equipment required at various capacity output rates and length of season. The principal variations among the methods studied involve the degree of mechanization associated with the case-fill and case-seal operation. Method B—manual fill, mechanical seal—has the lowest cost for casing combinations of retail and institutional cartons.

Total annual cost for the separate field and plant processing activities are obtained by aggregating costs representing efficient stage organization, along with general cost components not associated with specific operating stages. The planning cost equation for field operations is obtained by combining the equation representing costs of vining with that representing the cost of viners-to-plant transportation. The expression so derived is repeated below.[1/]

$$TSC_A = \$3,929 + \$2,633(R) + \$0.3691(H) + \$7.99(R)(H) + \$1.40(\log_{10} D)(R)(H)$$

[1/] The variables in these equations are:

(R) is 1,000 pounds of capacity output per hour.
(H) is total number of hours operated during the season.
(D) is distance of haul from viners to plant, expressed in logarithms to base 10.
(P) is percentage manual grade-out.
(H_r) is hours operated per season, retail style.
(H_i) is hours operated per season, institutional style.
(H_b) is hours operated per season, bulk style.

TSC_A is total season cost of field and assembly operations.
TSC_P is total season cost of in-plant processing operations.

The planning cost equation for in-plant processing is obtained by combining the planning equations representing costs of the individual operating stages and general cost components of in-plant processing operations. This expression is:[1]

$$TSC_p = \$15,353 + \$1,870(R) + \$27.6177(H) + \$18.3142(R)(H) + \$0.1110(P)(R)(H) + \$32.682(H_r)(R) + \$19.192(H_1)(R) + \$4.590(H_b)(R)$$

Before the above equations are combined into a planning cost equation representing total annual costs for over-all processing operations--of both field and plant--the least-cost combination of hours operated per season and hourly output rates of field and plant operations was determined. For the range of operating conditions specified, analysis demonstrated that efficient handling of any season volume of Lima beans for freezing calls for plant and vining facilities of capacities such that operations are for the maximum numberr of hours available during the season except in cases where the season is relatively long and the total season volume relatively small. In the volume range excepted, costs are lower with planned plant capacity exceeding that of the vining facilities.

The separate planning equations for field and plant operations are then combined to give a planning cost equation for the over-all processing operation which closely approximates least-cost integration of field and plant facilities. The planning equation so derived is used to demonstrate how variations in the variables--size of plant, length of operating season, percentage manual grade-out, style of pack, and distance of haul--affect average and total costs of processing Lima beans for freezing.

The study indicates that average costs per unit of output decrease with increases in the scale of operations and length of season. In terms of plant capacity, advantages of increased size are substantial in lower capacity plants but become relatively small in plants above 20,000 pounds per hour capacity. For any given capacity output rate, relatively large reductions in average cost are indicated as the length of season is increased. However, economies associated with increased length of season become relatively less important for seasons in excess of 750 hours.

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[1] *Ibid.*

A considerable amount of flexibility is provided in the design of plants synthesized. Inclusion of facilities for temporary storage prior to the blanching operation provides some insurance against hour-to-hour variations in plant receipts. Large variations in the proportions packed in the various size containers and grades are possible through provision of filling and casing equipment capable of handling any given plant "through-put" in either retail, institutional, or bulk containers. Although the costs developed in this report are based on constant rates of output, the plants are designed with enough flexibility to operate efficiently over a range of output rates near the optimum.

Although many Lima bean freezing plants in California have achieved a relatively high degree of efficiency, the selection of more economical techniques and movement toward increased hours of operation per season and larger plants could lead to further cost reductions. While many of the savings could be achieved in the short run, some of the cost-reduction possibilities involve changes in plant facilities and design which may be economical only as existing facilities are worn out and replaced. The material that has been presented should provide useful guides of Lima bean freezing plant operators interested in planning new or modernized facilities and for firms contemplating reorganization and consolidation of plants.

APPENDIX A

Table 1

Summary of Equipment and Installed Replacement Costs, Lima Bean Freezing Plants, California, 1958

Item				Estimated replacement cost dollars	Unit
Blanching equipment					
Blanchers					
Type A, 12-foot cylinder				3,071	each
Type B, 15-foot cylinder				3,428	each
Type C, 18-foot cylinder				3,790	each
Temperature controller, dual control				686	each
Varispeed drive assembly				706	each
Boilers					
Boiler h.p.	Steam pounds per hour	Heating surface square feet	Capacity, beans pounds per hour		
20	690	108	5,000	3,063	each
27	932	146	10,000	3,344	each
50	1,725	270	15,000	4,313	each
54	1,863	292	20,000	4,313	each
74	2,453	400	25,000	5,594	each
81	2,794	437	30,000	7,219	each
Casing equipment					
Case-in table, per 4-foot section				75	each
Casing machine, 10-ounce, with dump conveyor attachment				3,214	each
Sealer and compressor unit					
Type A, 28-foot compressor				6,460	each
Type B, 20-foot compressor				5,832	each
Type C, 12-foot compressor				4,998	each
Case stitching machine, 12-inch throat				675	each
Stencil table, wheel, and pad				60	each
Tally desk, single drawer				30	each
Glue stand, trough type				25	each
Case materials, shook, glue, wire					
Cases, 24 10-ounce, 4 panels, 2 colors				90	1,000 cases
Cases, 12 2½-pound, 4 panels, 2 colors				107	1,000 cases
Glue				75	100 gallons
Wire				28	100 pounds
Cleaning equipment					
Flotation washers with destoner attachment					
Type A, capacity 5,000 pounds per hour				2,789.00	each
Type B, capacity 6,500 pounds per hour				3,089.00	each
Type C, capacity 7,500 pounds per hour				3,389.00	each
Cleaner, shaker type, double sieves				1,460.00	each
Cleaner, pneumatic					
Type A, 18-inch intake, 3 h.p., capacity 7,500 pounds per hour				1,488.00	each
Type B, 24-inch intake, 7½ h.p., capacity 10,000 pounds per hour				2,698.00	each
Type C, 30-inch intake, 7½ h.p., capacity 12,500 pounds per hour				2,788.00	each
Type D, 36-inch intake, 7½-10 h.p., capacity 15,000 pounds per hour				3,050.00	each
Type E, 42-inch intake, 7½-10 h.p., capacity 20,000 pounds per hour				3,136.00	each
Container filling equipment					
Carton filling machines					
Type A, 10-ounce, capacity 7,500 pounds per hour				4,065.00	each
Carton form and close equipment (annual rental)				1,328.00	each
Type B, 10-ounce, capacity 10,000 pounds per hour (annual rental)				2,115.00	each
Type C, 2½-pound, capacity 12,750 pounds per hour				4,065.00	each
Carton form and close equipment (annual rental)				1,328.00	each
Bulk tray filler (for tray freeze, IQF), capacity 10,000 pounds per hour				1,123.00	each
Bag filler (IQF bag or case fill, manually operated)				480.00	each
Cluster breaker, capacity 10,000 pounds per hour				1,200.00	each
Hoppers, accumulating					
Type A, 45 cubic feet				175.00	each
Type B, 108 cubic feet				358.00	each
Wrappers					
Retail, capacity 7,500 pounds per hour				12,425.00	each
Institutional, capacity 12,750 pounds per hour				10,500.00	each
Packaging materials					
Cartons, 10-ounce, 5-1/4 x 1-3/8 x 4 inches; 0.015 solid bleach, sulphate				9.77	1,000 cartons
Cartons, 2½-pound, 9½ x 5¼ x 2½ inches; 0.020 special solid, manila				23.71	1,000 cartons
Bags, 55-pound, plain; multiwall, 1/40 wax, 6-inch tuck-in sleeve				129.00	1,000 bags
Overwraps, 10-ounce, 5-color print				4.02	1,000 wraps
Overwraps, 2½-pound, 2-color print				7.54	1,000 wraps
Conveyor equipment					
Conveyor frame, complete					
Belt or mesh type				10.30	foot
Spiral type				14.50	foot
Motor and drive assembly					
1/4 h.p.				247.00	each
1/2 h.p.				247.00	each
3/4 h.p.				280.00	each
1 h.p.				347.00	each
3 h.p.				474.00	each
5 h.p.				594.00	each
Box turn and/or converger unit				480.00	each
Magnetic switch, forward-reverse-stop, push button				87.00	each
Skate wheel conveyor, 12 inches wide				5.00	foot
Steel roller conveyor, 12 inches wide				7.00	foot
Flume, g.i., 20 gauge, unseamed				7.00	foot
Belting					
4-ply rubber cannery $0.41 (W)(L)				a/	a/
3-ply neoprene $0.43 (W)(L)				a/	a/
Wire mesh drain belt $0.42 (W)(L)				a/	a/
Drip pan				7.00	foot
Product pump assembly					
3-inch product pump, including intake tank				695.00	each
4-inch product pump, including intake tank				900.00	each
Dewater shaker and return water tank				670.00	each
Dewater reel and return tank (pick-belt type)				375.00	each
Tubing and fittings d/					
Quality grading equipment					
Flotation graders					
Type A, capacity 5,000 pounds per hour				2,589.00	each
Type B, capacity 6,500 pounds per hour				2,889.00	each
Type C, capacity 7,500 pounds per hour				3,189.00	each
Brine mixing and holding tank (salt capacity 1,200 pounds)				915.00	each
Brine density controller				900.00	each
Platform for brining station no. 1				3.40	square foot
Pick belts				--c/	--c/
Temporary product storage equipment					
Icing equipment					
Type A, 3-h.p. crusher, without blower				1,048.00	each
Type B, 3-h.p. crusher, with 10-h.p. blower and attachments				1,863.00	each
Type C, 3-h.p. crusher, without blower but with additional tank				1,257.00	each
Scoop shovels				5.00	each
Temporary storage tanks					
Type A, 700 cubic feet				785.00	each
Type B, 525 cubic feet				665.00	each
Type C, 550 cubic feet				550.00	each
Vining equipment					
Viner, stationary, complete				5,215.00	each
Power fork attachment				807.00	each
Side delivery conveyor				280.00	each
Vine feed regulator				365.00	each
Viner, mobile, complete				12,000.00	each
Tractor, 2-plow, with 6-foot detachable loader frame assembly				2,100.00	each
Truck, 2½-ton				2,200.00	each
Bins, tote, 4' x 4' x 4'				14.00	each

a/ Computed from above equations in which W is width of belt in inches and L is length of conveyor in feet.

b/ Dashes indicate nothing to enter.

c/ See cost data for conveyor equipment.

d/ Tubing and Fittings

Item	Installed cost 3-inch polyethylene	Installed cost 4-inch aluminum	Unit
Tubing	$ 0.70	$ 1.00	foot
90-degree elbow	1.90	16.00	each
Adapter or coupling	1.47	12.00	each
Tee	2.75	3.00	each
Valves	30.00	30.00	each
Hangers	0.59	0.59	each
Clamps	0.40	--b/	each
Install	2.00	2.00	foot
Contingencies	10 per cent	10 per cent	total cost

(Continued on next page.)

Appendix A, Table 1 continued.

Investment costs for water piping

Five-inch installation, main run 18 feet above plant floor, 18 tap-ins to equipment with drops averaging 15 feet per equipment item. Delivery volume at 60 pounds per square inch is 700 gallons per minute. (For a plant of approximately 12,500 pounds of beans per hr.)

Item	Size	Quantity		Unit	Extension	Discount	Total
	inches			dollars		per cent	dollars
Pipe	5	200 feet		2.98	596.00		
Pipe	2	60 feet		0.63	37.80		
Pipe	1-1/2	75 feet		0.46	34.50		
Pipe	1-1/4	500 feet		0.39	195.00		
			Subtotal		863.30		863.30
Check	1-1/2	4		8.76	35.04	20	
Valve	1-1/4	18		9.29	167.22	20	
Valve	1-1/2	18		11.90	214.20	20	
Valve	2	8		16.87	134.96	20	
Valve	5	1		77.82	77.82	20	
			Subtotal		629.24	20	503.40
Union	1-1/4	18		2.85	51.30	75	
Union	1-1/2	18		3.45	62.10	75	
Union	2	8		4.30	30.10	75	
			Subtotal		143.50	75	35.88
Nip	1-1/4	60		0.84	50.40	75	
Nip	1-1/2	60		1.00	60.00	75	
Nip	2	25		1.29	32.25	75	
			Subtotal		142.65	75	35.66
Reducer tee	5	14		26.00	364.00	38	
90-degree el	5	6		15.00	90.00	38	
90-degree el	1-1/4	36		0.66	23.76	38	
90-degree el	1-1/2	30		0.88	26.40	38	
90-degree el	2	18		1.25	22.50	38	
			Subtotal		526.66	38	326.53
Hanger	5	20		0.95	19.00		
Hanger	2	6		0.44	2.64		
Hanger	1-1/2	8		0.37	2.96		
Hanger	1-1/4	50		0.35	17.50		
			Subtotal		42.10		42.10
Rod	3/8	180 feet			12.50		
Rod	5/8	60 feet			12.50		
C clamp	3/8	65		0.47	30.55		
C clamp	5/8	20		0.88	17.60		
			Subtotal		73.15		73.15
J fountain	--b/	6		42.00	242.00		
Boiler hookup	--	1		500.00	500.00		
Hot water heater	--	2		100.00	200.00		
			Subtotal		942.00		942.00
Extra							358.00
			Grand total				3,180.00
Labor--60 man days at $34.00 per day							2,040.00
Summary--5-inch installation							
Materials							$3,180.00
Labor							2,040.00
Equipment rental							1,220.00
Insurance							200.00
Supervision							200.00
Safety factor							680.00
Profit							750.00
Total for job							$8,270.00
Summary--6-inch installation (For a plant of approximately 30,000 pounds of beans per hr.)							
Materials							$ 9,300.00
Labor, insurance, supervision, safety, and profit							7,400.00
Total for job							$16,700.00

Item	Estimated replacement cost	Unit
	dollars	
Electrical equipment		
Panel--includes duct work, installation, panel, feeders, and disconnects, labor, materials		
400 amp.	815.00	each
1,200 amp.	2,500.00	each
Sub (or auxiliary) panels		
200 amp.	300.00	each
400 amp.	400.00	each
Main and branch runs--includes disconnect switches, push button starter, labor, and materials	125.00	per $\frac{1}{4}$-3 h.p. motor
	200.00	per 3-5 h.p. motor
	250.00	per $7\frac{1}{2}$ h.p. motor
	310.00	per 10 h.p. motor
Light fixtures with switch panels	15.00	per fixture
Inspection lights, 6-foot double fluorescent	70.00	per fixture

Item	Estimated replacement cost
	dollars, each
General and miscellaneous equipment items	
Lift truck, standard 4,000-pound capacity, pneumatic or cushion tires	5,775
Scales	
Check weigh, 3-pound capacity	190
Floor, 2,600-pound capacity	1,430
Platform, 50-pound capacity	260
Blow torch	14
Cleaner, steam, portable	965
Drill, hand, electric	80
Drill press	145
Grinder	55
Heater, water, gas	175
Laboratory equipment	
Scales	253
Blender	45
Sink, 66-inch, stainless top	325
Miscellaneous	up to 250
Pipe threaders, cutters, taps	50
Saw, band	80
Sewage screen	3,100
Sewage conveyor, screw or spiral type	550
Garbage tanks, 200-gallon	100
Garbage tanks, 300-gallon	150
Stencil cutter	295
Truck, hand	40
Vise, portable	35
Vise, stationary	60
Vise, pipe	60
Welder, arc, complete	395
Belt stitcher	30
Miscellaneous hand tools	up to 250

(Footnotes on preceding page)

APPENDIX A

TABLE 2

Summary of Labor Production Standards for Jobs Performed in Processing Lima Beans for Freezing California, 1958

Operating stage, job classification and description	Production standard	Wage rate
	units per hour	dollars
VINING		
Fork vines: Method A--Engage vines with hand fork; place fork load on vine feed conveyor.	400 pounds[a]	1.25
Methods B and C--Engage vines with electric fork; place fork load on vine feed conveyor.	950 pounds	1.25
Handle lugs: Method A--Place empty lugs under viner delivery chute, get full lugs and dump to main assembly conveyor.	800 pounds	1.25
Method B--Place empty lugs under viner delivery chute, get full lugs and dump to main assembly conveyor.	950 pounds	1.25
Attend fill: Methods A, B, and C--Position empty bin under main assembly conveyor chute, regulate fill, and perform minor housekeeping duties.	5,600 pounds	1.25
Operate lift truck: Methods A, B, and C--Unload empty bins from truck; get full bins from fill station; and load truck or set aside for temporary storage.	20,000 pounds	1.60
Operate tractor: Methods A, B, and C--Group vines for forkers, distribute straw in ensilage trench, and spot loads of incoming vines.	20,000 pounds	1.60
Haul vines: Methods A, B, and C--Operate truck between fields and vining station and supervise loading from draper loader in field.	880 pounds	4.50[b]
Cleanup station: Methods A, B, and C--Cleanup or housekeeping at stationary vining site/s.	4,000 pounds	1.25
VINING (continued)		
Cleanup field: Methods A, B, C, and mobile vining--Pickup vines left over from draper loaders and mobiles and perform miscellaneous tasks in fields.	4,000 pounds	1.25
Operate mobile viner: Drive mobile unit and regulate speed for optimum pickup and thresh and assist in servicing machine.	525 pounds	1.50
Attend mobile viner: Watch mechanical functioning, assist in loading truck, inspect disposal for inadequate threshing assist in servicing machine and may alternate with driver.	1,050 pounds	1.50
Supervision of stationary vining: Crew supervisor--Place and supervise vining crew and spot trucks.	30,000 pounds	1.60
General supervisor--Overall supervision of field and station; coordinate viner to plant deliveries; collect grower samples; and work closely with field man with respect to maturity, time of harvest, etc. and with plant manager.	30,000 pounds	2.25
Supervision of mobile vining: Supervise vining crew, coordinate viner-plant deliveries, and work closely with fieldman and plant management.	30,000 pounds	2.50
RECEIVING, CLEANING, AND INITIAL GRADING		
Bin handling method: Operate lift truck--unload full bins from truck at receiving station, set aside to temporary storage, load empty bins on truck for return to viners, place full bins on cradle dump, operate dump, and return empty bins to storage.	20,000 pounds	2.10

(Continued on next page.)

Appendix A, Table 2 continued.

Operating stage, job classification and description	Production standard units per hour	Wage rate dollars
RECEIVING, CLEANING, AND INITIAL GRADING (continued)		
Attend cleaning equipment (field)--Operate flotation cleaners, regulate flow of product, clean equipment, and perform minor housekeeping duties.	10,000 pounds	1.25
Icing bins for intransit storage--Operate ice crushing machine, add ice to bins with scoop, and minor housekeeping.	7,500 pounds	1.25
Attend quality grading equipment, plant--Operate flotation graders, mix brine solution, maintain proper brine concentration, service equipment, and regulate product flow.	10,000 pounds	2.10
Bulk handling method:		
Attend bulk dump--Regulate flow from dump truck to receiving tank; regulate product flow from shaker feed through trash separator, pneumatic cleaner, and flume assembly; and minor housekeeping.	20,000 pounds	1.86
Attend cleaning equipment--Same as with bin handling method.	10,000 pounds	1.86
Attend quality grading equipment--Same as with bin handling method.	10,000 pounds	2.10
Diversion to temporary storage and in-plant icing operations--Distribute separate grades to temporary storage tanks, operate ice crusher and add ice to tanks with blower attachment, and distribute grades to blanch as required.	7,500 pounds	1.86
BLANCHING AND SECOND-QUALITY GRADE		
Attend blanch equipment: Operate blancher, maintain proper blanch temperature, regulate product flow through blanch, attend cooling flumes, and assist in servicing equipment.	10,000 pounds	2.10
Boiler room attendant: Fire and regulate boiler, maintain proper steam pressure, service equipment, assist in equipment repair, and housekeeping.	30,000 pounds	2.10
BLANCHING AND SECOND-QUALITY GRADE (continued)		
Attend grading equipment: Operate flotation graders, mix brine solution, maintain proper brine concentration, service equipment, and regulate product flow.	10,000 pounds	2.10
VISUAL INSPECTION AND MANUAL QUALITY GRADE		
Inspect beans on inspection tion belt for defects and overmatures, skins, and pieces and remove defectives and whites.	varies	1.69
$N = 5.101 + 0.892(R) + 0.0656(R)(P)$ N = number of sorters required R = rate of plant output per hour P = percentage grade-out by count		
PACKAGING RETAIL AND INSTITUTIONAL CARTONS		
Feed cartons: Get flat cartons from case and place in chute leading to carton forming machine.		
10-ounce cartons	19,500 cartons	1.69
2½-pound cartons	5,100 cartons	1.69
Attend carton filler: Operate filler, remove jams, and regulate flow.		
10-ounce cartons	19,500 cartons	1.69
2½-pound cartons	5,100 cartons	1.69
Check weigh cartons: Inspect for proper fill, weigh cartons, and remove over-under cartons from packaging line.		
10-ounce cartons	9,750 cartons	1.69
2½-pound cartons	2,500 cartons	1.69
Tray-off cartons: Get empty tray from freezer skid and place on tray-off stand, grasp cartons and slide into tray, and place full tray in freezer skid.		
10-ounce cartons	5,130 cartons	1.86
2½-pound cartons	2,550 cartons	1.86

(Continued on next page.)

Appendix A, Table 2, continued.

Operating stage, job classification and description	Production standard units per hour	Wage rate dollars
PACKAGING RETAIL AND INSTITUTIONAL CARTONS (continued)		
Wrapper man: Get rolls of overwraps from temporary storage, place in wrapper, operate wrapper, make adjustments, and service.		
10-ounce cartons	19,500 cartons	2.10
2½-pound cartons	5,100 cartons	2.10
Supply skid for cartons: Get skid from temporary storage and transfer to tray-off station, get full skid from tray-off station, tally out, and transfer to freezing tunnel.		
10-ounce cartons	19,500 cartons	1.86
2½-pound cartons	5,100 cartons	1.86
Supply packaging materials: Get cases of flat cartons from temporary storage, cut open case for carton feeder, remove empty cases and trash, get rolls of overwraps and arrange for wrapper man, and minor housekeeping duties.		
10-ounce cartons	19,500 cartons	1.86
2½-pound cartons	5,100 cartons	1.86
PACKAGING, BULK		
Feed trays: Get empty tray from freezer skid and set on power conveyor leading to try filler.	200 trays	1.86
Attend tray filler: Operate tray fill hopper, close and open hand-operate gate lever, and regulate product flow.	200 trays	1.86
Tray off: Get trays of loose beans from filler conveyor and set off to freezer skid.	200 trays	1.86
Supply skid: Get empty skid of trays from temporary storage, truck to tray fill station, get full skid of trays and truck to freezing tunnel, and get skid of loose frozen beans from freezing tunnel and truck to cluster breaker.	400 trays	1.86
PACKAGING, BULK (continued)		
Dump trays to cluster breaker: Get full tray of loose frozen beans from freezer skid, dump tray to cluster breaking machine, and return empty trays to skid.	50 trays	1.86
IQF fill: Get and form bag or case, place beneath bulk filler, and fill bag and set aside for check weighing.	50 bags or cases	1.86
Check weigh bulk containers: Get full bag or case, weigh on floor scale, add or remove product to make proper weight, set aside to closing and palletizing area.	50 bags or cases	1.86
Set off to pallet: Get and close bag or case and set off to pallet.	50 bags or cases	1.86
CASING OPERATION, CARTONS		
Stencil or stamp case: Methods A and D--Obtain bundles of flat cases from temporary storage, remove twine binding, stencil, and aside to case form station.		
24/10-ounce cases	790 cases	1.69
12/2½-pound cases	700 cases	1.69
Form case: Methods A and D--Get stenciled case from table, form, stitch bottom, and set aside to case-in station.		
24/10-ounce cases	345 cases	1.69
12/2½-pound cases	315 cases	1.69
Methods B and C--Get flat case from table and form, aside to case-in station.		
24/10-ounce cases	549 cases	1.69
12/2½-pound cases	494 cases	1.69
Dump tray frozen cartons: Methods A, B, C, and D--Get full trays from freezer skid and dump to case-in table or conveyor, return empty trays to freezer skid.		
10-ounce cartons	334 cases	1.86
2½-pound cartons	334 cases	1.86

(Continued on next page.)

Appendix A, Table 2, continued.

Operating stage, job classification and description	Production standard	Wage rate
	units per hour	dollars
CASING OPERATION, CARTONS (continued)		
Fill case:		
Methods A and B--Get case, fill with cartons, and push aside on case-in conveyor		
24/10-ounce cartons	213 cases	1.86
12/2½-pound cartons	200 cases	1.86
Methods C and D--Get case and place over sleeve feed of machine caser, hold in place, and operate casing machine.		
24/10-ounce cartons	576 cases	1.69
Methods C and D--Get case, fill with cartons, and push aside on case-in conveyor.		
12/2½-pound cartons	200 cases	1.69
Guide cartons: Methods C and D--Get and arrange 10-ounce cartons in single file on machine caser lead-in conveyor.	576 cases	1.69
CASING OPERATION, CARTONS (continued)		
Seal and palletize case: Methods A and D--Apply glue to top flaps, close flaps, and set aside to pallet.		
24/10-ounce cartons	300 cases	1.86
12/2½-pound cartons	290 cases	1.86
Supply casing materials: Methods A, B, C, and D--Get case shook from temporary storage, hand truck to casing station, assist in transfer of case material among stencil and form areas, and minor housekeeping.	815 cases	1.86
Talley out: Methods A, B, C, and D--Record number of cases per pallet load with respect to grade, style, and label.	30,000 pounds	1.69
IN-PLANT TRANSPORTATION OF CASED GOODS AND PACKAGING MATERIALS		
Lift truck operator	20,700 pounds	2.10

a/ Units per hour in pounds are in shelled weight.

b/ Wage rate includes driver and truck (contract basis).

APPENDIX B

The Minimum Cost Combination of Hours of Operation and Rates of Output of Field and Plant Operations in Processing Lima Beans for Freezing

Equations (26) and (27) representing total annual planning costs of field and plant operations were given on pages 78 and 80 of the text. These equations can be expressed solely in terms of rates of output (R) and hours operated per season (H) by specifying particular values for the variables D, P, H_r, H_i, and H_b, that is:

$$(26) \quad TSC_A = \$3,929 + \$2,633(R_1) + \$0.3691(H_1) + \$A_1(R_1H_1)$$

$$(27) \quad TSC_P = \$15,353 = \$1,870(R_2) + \$27.6177(H_2) + \$A_2(R_2H_2)$$

where the coefficients A_1 and A_2 depend on the values specified for the variables D, P, H_r, H_i, and H_b.

As total season volume is defined as $R_1H_1 = R_2H_2 = q$, the above equations can be written solely in terms of (H's) and (q), that is:

$$(26) \quad TSC_A = \$3,929 + \$2,633(q/H_1) + \$0.3691(H_1) + \$A_1(q)$$

$$(27) \quad TSC_P = \$15,353 + \$1,870(q/H_2) + \$27.6177(H_2) + \$A_2(q)$$

since $R_1 = q/H_1$ and $R_2 = q/H_2$.

Also, these equations can be expressed as daily cost equations by dividing the constant terms and the coefficients of q/H_1, q/H_2, and q by the number of days operated per season. For each length of season (number of days operated) specified, the optimum values of H_1 and H_2 and R_1 and R_2 can be found that minimize the combined costs of field and plant operations. The solution presented below assumes a 40-day operating season. Solutions for seasons of different length are presented later in this appendix.

$$C_1 = 98.225 + 65.825\frac{Q}{H_1} + 0.3691 H_1 + A_1Q$$

$$C_2 = 383.825 + 46.750\frac{Q}{H_2} + 27.6177 H_2 + A_2Q$$

where

C_1 = total daily costs of vining and assembly,

C_2 = total daily costs of in-plant processing,

Q = total daily volume vined and processed in 1,000 pounds

H_1 = hours of vining per day,

H_2 = hours of in-plant processing per day,

$\frac{Q}{H_1}$ = R_1 hourly rate of vining in 1,000 pounds,

$\frac{Q}{H_2}$ = R_2 hourly rate of in-plant processing 1,000 pounds,

and where the values of A_1 and A_2 depend on the values specified for the variables D, P, H_r, H_i, and H_b in equation (26) and (27)

With the maximum number of daily operating hours specified at 16 hours and a maximum temporary storage allowance of 8 hours per day, the optimum combination of daily hours and output rates is obtained by minimizing $C = C_1 + C_2$ subject to the constraints, that is:[1]

$$H_1 - H_2 \leqq 8$$
$$H_2 - H_1 \leqq 8$$
$$H_1 \leqq 16$$
$$H_2 \leqq 16$$

These constraints are graphically depicted in Figure A. Every point on the graph corresponds to a pair of values for H_1 and H_2. Any point inside or on the boundary lines of the figure (OABCDE) corresponds to combinations of H_1 and H_2 that simultaneously satisfy all the constraints.

The solution to this problem is simplified by first assuming there are no effective restrictions on daily hours of operation and that H_1 and H_2 are free to vary up to 24 hours per day with no increase in cost rates. In this case, equations C_1 and C_2 are minimized separately, that is:

---

[1] As the unit cost of temporary storage operations averages less than five-tenth of a mill per pound, the total daily cost function ($C = C_1 + C_2$) was not adjusted for these costs for each of the constraints on H_1 and H_2. Adjustment of the daily cost functions to account for variations in temporary storage costs as the constraints vary would have no significant effect on the solution obtained.

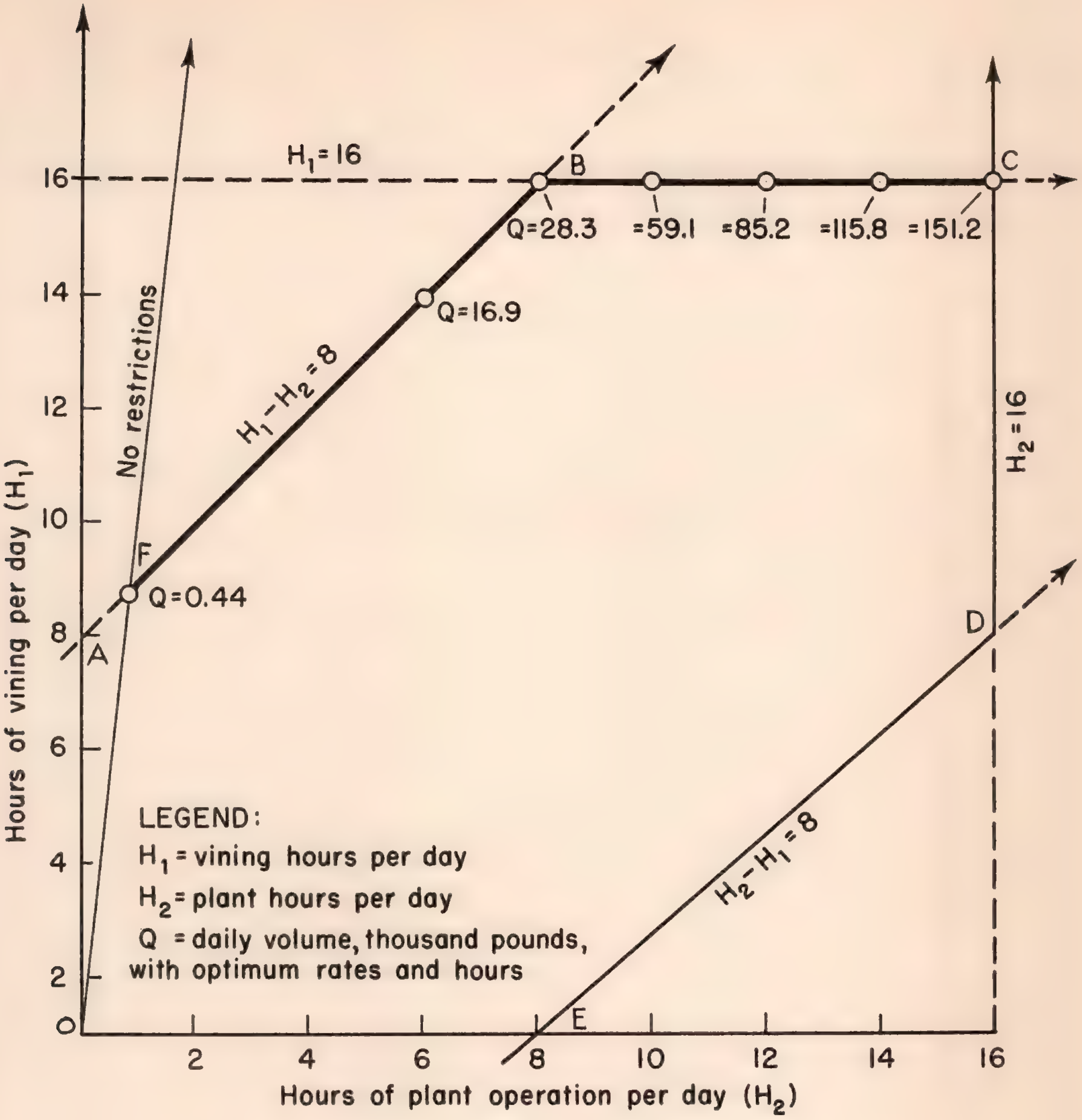

Figure A. Feasible and Optimal Combinations of Daily Hours of Field and Plant Operations for Frozen Lima Bean Processing, California, 1958

$$\frac{dC_1}{dH_1} = \frac{-65.825(Q)}{H_1^2} + 0.3691 = 0$$

$$\frac{dC_2}{dH_2} = \frac{-46.75(Q)}{H_2^2} + 27.6177 = 0$$

$$H_1 = 13.354 \sqrt{Q}$$

$$H_2 = 1.301 \sqrt{Q}$$

Thus, the locus of cost-minimizing combinations of H_1 and H_2 for alternative values of Q is given by the equation:

$$H_1 = 10.264(H_2)$$

If Q is allowed to increase from zero along the "expansion path" defined by the preceding equation, it is clear that the first constraint to become effective is that associated with $H_1 - H_2 = 8$ (Point "F", Figure A). The values for H_1 and H_2—and, consequently, for R_1, R_2, and Q—for which this constraint first becomes binding, are found by solving the pair of equations:

$$H_1 - H_2 = 8$$

$$H_1 = 10.264(H_2)$$

These equations imply that $H_1 = 8.86$, $H_2 = 0.86$, and $Q = 0.440$, and is unrealistic.

For larger values of Q, the cost-minimizing "expansion path" follows the line $H_1 - H_2 = 8$. In other words, the next step is to minimize the function C subject to the single condition that $H_1 - H_2 = 8$.

Let $\phi = C - \lambda\,(H_1 - H_2 - 8)$, where λ is a Lagrange multiplier.

$$\frac{\partial\phi}{\partial H_1} = -\frac{65.825(Q)}{H_1^2} + 0.3691 - \lambda = 0$$

$$\frac{\partial\phi}{\partial H_2} = -\frac{46.75(Q)}{H_2^2} + 27.6177 + \lambda = 0$$

Adding these two equations and clearing of fractions results in

$$-65.825(Q)(H_2^2) + 27.9868(H_1^2)(H_2^2) - 46.75(Q)(H_1^2) = 0.$$

This equation can be solved for H_1 and H_2 by noting that $H_1 = H_2 + 8$. Rather than solving it explicitly, however, it is easier to specify a point on the line $(H_1 - H_2 = 8)$ and use the above equation to find the corresponding Q. For example, if H_1 is set at 14 hours and H_2 set at 6 hours, this equation implies that $Q = 16.9$.

Movement along this line can proceed with increasing daily volume (Q) until H_1 reaches its absolute limit of 16 hours. At this point (point "B", Figure A), the value of H_1 is 16 and the value of H_2 is 8. With these values on H_1 and H_2, the daily volume Q implied by the above equation is 28.3. At this value of Q, the "expansion path" becomes the horizontal line $H_1 = 16$. With H_1 fixed at 16 hours per day, C can be minimized for Q greater than 28.3 by minimizing C_2 independently, or as derived above, $H_2 = 1.301 \sqrt{Q}$. For example, if $Q = 85.2$, the cost minimizing value of H_2 is 12 hours.

As Q increases further, H_2 can expand to its absolute limit of 16 hours (point "C", Figure A), which corresponds to $Q = 151.2$. No further adjustment of H_1 and H_2 is possible as Q expands and increasing daily volume beyond $Q = 151.2$ can only be achieved with proportional increases in the hourly output rates (size of vining and plant facilities).

The number of days operated per season has an important effect on the least-cost combination of daily operating hours and hourly rates of output. However, the effect on rates and hours is directly proportional to the length of season. With a 30-day operating season, for example, the total daily volume (Q) corresponding to point C of Figure A is 113.4, exactly three-fourths of the value for Q with a 40-day operating season. Similarly, the daily volume corresponding to point B is 21.2 (three-fourths times 28.3) for a 30-day season. Appendix B, Table 1 gives selected values for combinations of hours and rates of field and plant operations for a 30-, 40-, and 50-day operating season on both a daily and season basis.

The development presented in the text, pages 78 to 86 inclusive, assumed that daily operation of vining and plant facilities for the full amount of time available per day gave results closely approximating optimum combination of hours and rates for vining and plant operations. The preceding development demonstrates that, under the operating conditions specified, such an approximation is the optimum except in cases of relatively low daily volumes and relatively long operating seasons.

APPENDIX B

TABLE 1

Minimum Cost Combinations of Hours Operated and Rates of Output for Field and Plant Operations in Processing Lima Beans for Freezing for Three Lengths of Operating Season, California, 1958

Hours operated per day		Daily volume	Season volume	Hourly rate of output	
Field	Plant			Field	Plant
H_1	H_2	Q	q	R_1	R_2
		thousand pounds	million pounds	pounds	
		30-day season			
16	8	21.254	0.637	1,328	2,657
16	10	44.304	1.329	2,769	4,430
16	12	63.890	1.917	3,993	5,324
16	14	86.848	2.605	5,428	6,203
16	16	113.418	3.403	7,089	7,089
16	16	150.000	4.500	9,375	9,375
16	16	200.000	6.000	12,500	12,500
16	16	300.000	9.000	18,750	18,750
16	16	400.000	12.000	25,000	25,000
		40-day season			
16	8	28.338	1.134	1,771	3,542
16	10	59.072	2.363	3,692	5,907
16	12	85.186	3.407	5,324	7,099
16	14	115.797	4.632	7,237	8,271
16	16	151.224	6.049	9,452	9,452
16	16	200.000	8.000	12,500	12,500
16	16	300.000	12.000	18,750	18,750
16	16	400.000	16.000	25,000	25,000
		50-day season			
16	8	35.423	1.771	2,214	4,428
16	10	73.840	3.692	4,615	7,384
16	12	106.483	5.324	6,655	8,874
16	14	144.746	7.237	9,046	10,339
16	16	189.030	9.452	11,814	11,184
16	16	200.000	10.000	12,500	12,500
16	16	300.000	15.000	18,750	18,750
16	16	400.000	20.000	25,000	25,000